# ADDENDUM C:

## DRAFT FINAL

## Plan for Marine Ecological Risk Assessment

for

## Old Fire Fighting Training Area
## Naval Education and Training Center
## Newport, Rhode Island

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**PROJECT NAME:** Offshore Ecological Risk Assessment for Old Fire Fighting Training Area

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## 1.0 BACKGROUND

This addendum has been prepared to supplement the Work/Quality Assurance Project Plan, Narragansett Bay Ecorisk and Monitoring for Navy Sites, referred to herein as the "Master Work Plan". This addendum has been prepared to describe the methodology to perform a baseline ecological risk assessment for the Old Fire Fighting Training Area, which is part of the Naval Education and Training Center (NETC), located in Newport, RI.

The Master Work Plan presents generic background information concerning the approaches to problem formulation, exposure and ecological effects assessments, and QA/QC requirements and activities. The intent of the Work Plan is to present a consistent approach to assess ecological risks for several Navy sites in Narragansett Bay.

This addendum presents the site specific ecological risk assessment activities and the sampling and analysis plan for Old Fire Fighting Training Area. This addendum includes descriptions of existing data, and a plan to supplement that data with additional information that is required for the performance of an ecological risk assessment for this site.

### 1.1 SITE DESCRIPTION

The information provided in this section has been adapted from the Draft Final "Old Fire Fighting Training Area Ecological Risk Assessment Report," by TRC Environmental Corporation, October 1994.

The Old Fire Fighting Training Area site occupies approximately 5.5 acres at the northern end of Coasters Harbor Island (Fig. C1-1). A building, picnic area, playground and baseball field are at the site. Two soil mounds were present in 1994: a 20-foot-high mound in the center of the site and a 6-foot-high mound in the western corner of the site. The topography slopes slightly from south to north, with the northern edge of the site slightly higher in elevation than the shoreline of the Bay. Small ponded areas occur on the site during periods of heavy rain.

"The site was used for fire fighting training from the 1940's until 1972. A network of underground piping was used to carry a water/oil mixture to the site. The mixture was reportedly sprayed onto the training buildings and set on fire.

In 1987, oily subsurface soils were discovered during completion of geotechnical borings for a building expansion. Environmental investigations during the RI included ambient air and radiological surveys, a geophysical survey, a soil gas survey, surface soil sampling, test borings, test pits, and ground water monitoring well installations and sampling. In addition, offshore investigation activities, including sediment and bivalve sampling (clams and mussels), were conducted along the shoreline of the site between the Phase I and Phase II RI (TRC, 1994)."

## 1.2 SUMMARY OF PREVIOUS SITE INVESTIGATIONS

This summary presents the general findings of previous environmental investigations at Old Fire Fighting Training Area, with particular emphasis on their relationship to potential risks to ecological receptors in Narragansett Bay. Detailed information regarding the findings of these studies with respect to Problem Formulation is presented in Section 2.0 of this Addendum.

The findings of the RI and offshore investigation activities are presented in three reports (TRC, 1991, TRC, 1994, and Battelle, 1994). Below is a summary of those findings.

> The overburden materials consist of up to 10 feet of fill over till deposits. Bedrock was encountered at depths of 2 to 29 feet below the surface. Generally, site ground water flows north toward Narragansett Bay.
>
> Elevated levels of semi-volatile organic compounds (SVOCs) and inorganic contamination are present in the site soils. Overall, the greatest amount of soil contamination is present in surface soils located along the edge of the site, adjacent to Narragansett Bay, and in subsurface soils located in the central to western portion of the site. The highest concentrations of SVOCs and inorganics were typically detected from soils containing petroleum odors and/or staining. While the analytical data of the site soils does not indicate that the former activities at the site have significantly impacted the soils, petroleum staining and odors were noted in soil borings investigated throughout the central to western portions of the site. The soil boring and test pit soil samples exhibiting signs of petroleum contamination were typically collected at or below the ground water table indicating the contamination is very likely related to the ground water.
>
> Ground water sample results indicate that the past activities at the site have impacted the site ground water. Only one volatile organic compound (VOC) was present in one monitoring well and SVOC concentrations were relatively low in several ground water samples. However, petroleum odors were noted in the ground water during sampling of several monitoring wells located in the central to northern portion of the site. In addition, a sheen was noted on ground water purged from several of these monitoring wells. Inorganics were present in many of the ground water samples at concentrations exceeding maximum contaminant levels (MCLs). However, based on the filtered analysis conducted on five of the monitoring wells, it appears that the fine silt material in the ground

water samples may be a primary source of the more significant inorganic ground water contamination.

Offshore sampling indicates that elevated concentrations of polycyclic aromatic hydrocarbons (PAHs) were present in sediments and mussel samples located at the near shore locations. The source of the PAH contamination in the near shore samples may be attributed to the asphalt debris which is spread along the site's shoreline (TRC, 1994)."

## 1.3 OBJECTIVE AND SCOPE

In 1995 Brown and Root Environmental, formerly Halliburton NUS Corporation, contracted the University of Rhode Island to prepare this offshore ecological risk assessment work plan for Old Fire Fighting Training Area. The purpose of the work identified in this Addendum is to develop the information needed to evaluate ecological risks to ecological receptors in Coasters Harbor and Narragansett Bay from contaminants related to Navy activities in the Old Fire Fighting Training Area. The general approach taken in this investigation follows that described in the main body of the Master Work Plan (URI and SAIC, 1995).

The overall goal of this site-specific investigation is to use the U.S. EPA's Ecological Risk Assessment Framework and applicable EPA Region I guidance to generate and interpret the data required to complete the offshore ecological risk assessment for the NETC Old Fire Fighting Training Area. This Work Plan addenda follows the Master Work Plan with respect to the objectives of the site-specific ERA. Such objectives are:

- o To assess the ecological risks to offshore environments of Coasters Harbor and Narragansett Bay from chemical stressors associated with the Old Fire Fighting Training Area;
- o To develop information sufficient to make informed risk management decisions regarding remedial options on a site-specific basis; and
- o To support communication to the public of the nature and extent of the offshore ecological risks associated with the Old Fire Fighting Training Area.

Section 1 of the Master Work Plan describes the general requirements and data products of a site-specific ERA, including Problem Formulation, Exposure and Ecological Effects Assessments, and Characterization of Ecological Risks, as well as guidance used to meet these objectives.

In Problem Formulation, the activities will include:

- o Determination of the nature and extent of contamination of offshore media associated with the Old Fire Fighting Training Area;
- o Identification of contaminants of concern (CoCs);
- o Identification of the ecological receptors potentially at risk from site-related CoCs; and
- o Development of a s site-specific conceptual model of ecological risks associated with the Old Fire Fighting Training Area.

In the Exposure and Ecological Effects Assessment phases, activities will include:

- o Collection of information needed to quantify or estimate the concentrations of CoCs in the relevant environmental media;
- o Measurement of the toxicity of exposure media, and modeling exercises to predict the occurrence of adverse ecological impact.

Characterization of Ecological Risks activities will include:

- o Analysis of CoC concentration *versus* observations of adverse effects;
- o Analysis of CoC bioaccumulation;
- o Comparisons of toxicity evaluations with observed ecological effects;
- o Comparisons of exposure point concentrations with established standards and criteria for offshore media, and
- o Comparisons of exposure point concentrations with published information regarding the toxicity of CoCs.

The scope of activities described above will be conducted following procedures contained in the Master Work Plan, and incorporates comments provided by the Narragansett Bay Ecorisk Advisory Board. For reference, the following sections of the Master Work Plan should be consulted:

| Master Work Plan Section | Section Description |
|---|---|
| 3.0 | Data quality objectives, and sample collection and analysis procedures |
| 4.0 | Analytical procedures |
| 5.0 | Sample and data management procedures |
| 6.0 | Descriptions of site-specific ecological risk assessment reports |
| 7.0 | Health and Safety |
| 8.0 | References (except for those which are site-specific) |
| Appendices | Standard Operating Procedures (A); Chemistry and Toxicity Testing Quality Assurance and Quality Control (B), and Health and Safety Plan (C). |

Changes unique to the investigation of Old Fire Fighting Training Area are presented in this Addendum. The project-specific organization and responsibilities also are described in this Addendum.

Building upon the foundation provided in the master Work Plan, the sections that follow present results of the Problem Formulation for Old Fire Fighting Training Area, identify existing data gaps and approaches to obtaining the necessary data (Field Sampling and Analysis Plan), and propose Exposure Assessment, Ecological Effects Assessment, and Risk Characterization activities unique to Old Fire Fighting Training Area.

## 2.0 SITE-SPECIFIC PROBLEM FORMULATION

### 2.1 SITE CHARACTERIZATION

The primary objectives of the site characterization for this offshore ecological risk assessment are to identify the kinds and spatial extent of offshore habitats that are associated with the Old Fire Fighting Training Area, and identify the species and biological communities that may come in contact with site-related contaminants. The following site characterization for the Old Fire Fighting Training Area was extracted from the Ecological Risk Assessment (ERA) Report for Old Fire Fighting Training Area (TRC, 1994).

### 2.1.1. Old Fire Fighting Training Area Site Description

The Old Fire Fighting Training Area site is on Coasters Island, within the Narragansett Bay drainage basin. All surface water drainage from the basin is into the Bay. The local geology is characterized by an overburden of glacial deposits from 1 foot to 50 feet thick. Most of the glacial deposits are till, but some isolated outwash areas are present. Ground water in the general area is at depths from less than 1 foot to about 30 feet. The average depth to ground water is approximately 6 feet. Ground water at the site flows toward the Bay.

#### 2.1.1.1. Habitat Survey

Menzie-Cura & Associates, Inc., conducted qualitative reconnaissance surveys on May 9, 1994, to identify habitats and associated wildlife. Field biologists recorded observations in field notebooks and on film. The survey was qualitative, rather than quantitative, because the goal was to provide site-specific observations concerning the diversity (i.e., number and type) of species, rather than data for assessment of population structure or community analyses. The methods and detailed results of these surveys are provided in Menzie-Cura & Associates, Inc. (1994). The offshore benthic infaunal survey was conducted from August 23 to August 25, 1993.

The terrestrial habitat of the Old Fire Fighting Training Area site is a mowed grass lawn area with scattered Austrian black pines (2 to 4 meters tall) and red cedars (2 meters tall). The site is maintained for use as a softball field and playground. The grassy areas of the site extend to an adjacent cobble beach. The area appears to be a foraging area for birds which nest on buildings adjacent to the site.

The adjacent beach has a gravel to cobble shoreline, littered with construction debris such as cement aggregate, pieces of rebar, brick, boulders, and pieces of asphalt. The intertidal and near shore flora and fauna include: *Codium fragilis, Fucus vesiculosus, Balanus* species (as epifauna on the *Fucus* fronds), *Ulva lactuluca*, and various species of *Orchestia* under the *Fucus* fronds. These fauna were sparsely scattered in small beds at and below the tide line.

Sediments within the harbor off Coasters Island in the vicinity of the Old Fire Fighting Training Area site were found to be anaerobic. Anaerobic sediments, in general, are characterized by lack of oxygen, ferrous iron, ammonia, and hydrogen sulfide. It does not support abundant benthic fauna, and is mostly inhabited by anaerobic bacteria. Grabs collected in the inner harbor revealed a black sapropelic mud high in silt content. The extent to which sediments exhibited anaerobic conditions diminished with distance from the inner harbor toward Narragansett Bay. Beyond the mouth of the harbor, the sediments exhibited an oxidized sediment which supported abundant benthic fauna. These trends were confirmed in a qualitative survey conducted by URI in the fall 1995 (J. King, pers. comm.).

Benthic community structure analyses conducted on two offshore stations at the Old Fire Fighting Training Area revealed distinct community profiles (Fig. C2-1). At one station (Station OS-7; TRC 1994), the most abundant organisms were the opportunistic polychaetes *Capitella* spp. and *Streblospio benedicti*. These two species accounted for 65 percent of the individuals collected. A small bivalve, *Nucula annulata*, was represented by just 5 specimens in the three replicate samples; even lower numbers of oligochaetes, the polychaete *Polydora cornuta,* and the amphipod *Leptocheirus pinguis*, were found. High species diversity was observed at Station OS-7 but was somewhat lower than that of the reference station located at Jamestown Cranston Cove on Conanicut Island.

In contrast, faunal densities and richness at Station OS-8 was much higher (401 individuals/0.05 $m^2$, 54 species, respectively) than at Station OS-7. Oligochaetes were the dominant taxon at Station OS-8 (37 percent), but mollusks (*Crepidula* spp., *Fargoa bushiana, Nucula annulata, Tellina agilis*) and amphipods (*Microdeutopus* spp.) were present in significant numbers. Among the dominant species at Station OS-8 were the polychaetes *Streblospio benedicti* and *Mediomastus ambiseta*. Species diversity slightly exceeded that of the reference stations at Station OS-8.

2.1.1.2. Contaminant Data

This subsection provides a brief description of the contaminant distribution in environmental media for the Old Fire Fighting Training Area site based on TRC (1994). The same set of constituent analyses were performed on both the nearshore and offshore samples collected under the offshore investigation performed by Battelle Ocean Sciences. In addition, the data from one additional shoreline sediment sample collected under a separate part of the RI was analyzed for the full target compound/analyte list (TCL/TAL). VOC analysis was reported as not performed on the offshore investigation samples because of the high solubility and short half life of VOCs in the marine environment.

<u>Surface Soil Data</u>

The contaminants in surface soil most frequently detected were the inorganic constituents, SVOCs, and pesticides.

*Inorganic Constituents:* Of the 24 inorganic analytes investigated for occurrence in surface soil, 22 were detected. Roughly one-third of the maximum detected concentrations of inorganic constituents were observed at monitoring well, MW-11, with the remaining maximum detected concentrations distributed evenly across 11 other sampling locations. MW-11 is on the top of the bank bordering Narragansett Bay.

*Volatile Organic Compounds:* Of the 34 VOC target analytes for surface soil, 10 were found at detectable concentrations. Of these, five were present at a frequency of 5% or higher. VOCs were detected evenly across much of the site, with no more than a few detections at any one location. The concentrations of VOCs detected in surface soil ranged from 0.001 milligrams per kilogram (mg/kg) (2-butanone, methylene chloride, trichloroethene, and xylenes) to 0.017 mg/kg (total 1,2-dichloroethene).

*Semi-Volatile Organic Compounds*: Of the 67 SVOC target analytes for surface soil, 28 constituents were detected including 17 PAHs, four phthalates, two phenols, and five other constituents. The greatest number of detections of SVOCs were in surface soil samples collected from the following locations: at SS-20, B-8, B-9, B-16, B-17, MW-9, and MW-10. One or more SVOCs were detected in most of the other sampling locations. The maximum detected concentrations of SVOCs were observed at B-13 and B-16. The 17 PAHs detected in surface soil were present at a frequency of 5% or higher. The concentrations of all PAHs detected in surface soil range from 0.036 mg/kg (benzo(b)fluoranthene) to 2.8 mg/kg (benzo(a)pyrene). Two of the four phthalates detected in surface soil were present at a frequency of 5% or higher, bis(2-ethylhexyl)phthalate and di-n-butylphthalate. The concentrations of phthalates detected in surface soil range from 0.041 mg/kg (di-n-butylphthalate) to 0.59 mg/kg (bis(2-ethylhexyl)phthalate).

Three of the other five SVOCs detected in surface soil were present at a frequency of 5% or higher. These SVOCs were: carbazole (0.061 to 0.69 mg/kg), dibenzofuran (0.038 to 0.50 mg/kg), and dioxins/furans (detected in two of two samples analyzed at concentrations of 1.8E-05 to 2.5E-05 mg/kg expressed in terms of 2,3,7,8-tetrachloro-p-dibenzodioxin (TCDD) toxic equivalents). The congeners of dioxins/furans detected include total heptachlorodibenzofurans (HpCDFs) and octachlorodibenzofuran (OCDF). Note that 2,3,7,8-HpCDF was not analyzed for in surface soil.

*Pesticides:* Of the 21 pesticides analyzed for presence in surface soil, 19 were detected. Pesticides were detected in samples across the site, with a higher detection frequency in the Phase II versus Phase I samples. This latter trend is presumably due to the lower detection limits achieved during the Phase II sample analysis. Most of the maximum detected concentrations were observed at shore samples SS-17 and SS-18, and surface soil sample B-16, with the remaining maximum detected concentrations occurring evenly across six other sampling locations. SS-17 is in the western portion of the site near Taylor Drive. SS-18 is also in the western part of the site, but near the bank bordering Narragansett Bay. Of these, 18 were detected at a frequency of 5% or higher. The concentrations of pesticides detected in surface soil range from 2.4E-05 mg/kg (endosulfan II) to 0.074 mg/kg, 4,4-dichlorodiphenyl-trichloroethane (4,4'-DDT).

*PCBs:* Aroclor-1254 was detected at a concentration of 0.08 mg/kg in one of 38 surface soil samples (SS-1 from the eastern portion of the site) analyzed for PCBs. No other PCBs were detected in any other surface soil samples.

Shoreline/Nearshore Sediment Data

Inorganic constituents and PAHs were the most frequently detected analytes in shoreline and nearshore sediment (Table C2-1). One pesticide (4,4'-DDT) and one PCB (Aroclor-1254) were also detected (TRC,1994).

*Volatile Organic Compounds:* Of the 33 VOCs analyzed for presence in sediment samples (Phase I shoreline only), none were detected.

*Inorganic Constituents:* Twenty-four (24) of the 25 inorganics analyzed for presence in shoreline/nearshore sediment samples were detected. Nine metals considered to be of toxicological significance were detected (Table C2-1).

*Semi-Volatile Organic Compounds:* Of the 40 SVOCs analyzed for presence in shoreline/nearshore sediment, all were detected (Table C2-1). The PAH constituents detected included heterocyclic compounds such as dibenzothiophenes. The maximum detected concentrations of SVOCs were observed at the eastern portion of the site, near stations NS-1 and NS-2 (Figure C2-1).

The concentrations of SVOCs detected in shoreline/nearshore sediment samples ranged from 3.8 ng/g (biphenyl) to 5600 ng/g (fluoranthene).

Other SVOCs as reported in TRC,1994 detected in shoreline/nearshore sediment include: dibenzofuran (detected in three shoreline/nearshore samples at concentrations of 21 to 220 ng/g), and dioxins/furans (detected in the one sample analyzed for these constituents at a concentration of 0.012 ng/g expressed in terms of 2,3,7,8-TCDD toxic equivalents) (TRC,1994). The congeners of dioxins/furans detected in sediment (Phase I shoreline) include HpCDF and OCDF. Data for the compound 2,3,7,8-HpCDF was not reported for shoreline sediment stations. Data for nearshore stations (Figure C2-1) were reported as composites of NS1/2, NS3/4, and NS5/6 (Table C2-1). Only tissue data was reported for Station NS10.

*Pesticides:* Of the 20 pesticides analyzed for presence in one Phase I shoreline sediment sample from the eastern portion of the site, only 4,4-DDT was detected at a concentration of 2.3 ng/g (TRC,1994).

*PCBs:* PCB congeners were detected in all three shoreline/nearshore sediment samples analyzed for PCBs. Concentrations of total PCBs ranged from 24.6 to 62.5 ng/g. The maximum detected concentration was observed at the eastern portion of the site, near stations NS-1 and NS-2.

<u>Offshore Sediment Data</u>

*Volatile Organic Compounds:* VOCs were not analyzed for presence in offshore sediment.

Inorganic constituents, SVOCs, and PCBs were detected with 100% frequency in the offshore sediment samples. Most of the maximum detected concentrations of inorganics were observed in the eastern portion of the site (Table C2-1).

*Inorganic Constituents:* All of the inorganics analyzed for presence in offshore sediment were detected. Concentrations ranged from 0.1ug/g (Hg) to 215 ug/g (Zn).

*Semi-Volatile Organic Compounds*: All 40 of the SVOCs analyzed for presence in offshore sediment samples were detected in the four offshore samples, including 38 PAHs and two other constituents (biphenyl and dibenzofuran). The PAHs included heterocyclic compounds such as dibenzothiophene. The maximum detected concentrations of SVOCs were observed at the eastern portion of the site. Detected concentrations in offshore sediment range from 1.6 ng/g (biphenyl) to 1,499.1 ng/g (fluoranthene).

*Pesticides:* Offshore sediment samples were not analyzed for pesticides.

*PCBs:* PCB congeners were detected in the four offshore sediment samples at concentrations ranging from 0.3 ng/g to 5.2 ng/g. The maximum concentration of total PCBs (65.5 ng/g) was observed at the eastern portion of the site.

<u>Nearshore Shellfish Data</u>

Inorganic constituents, SVOCs, and Aroclor-1254 were the most frequently detected analytes in nearshore mussels and clams.

*Inorganic Constituents in Mussels*: Of the 24 inorganic constituents analyzed for presence in nearshore mussels, 20 were detected. Dibutyltin was detected in one nearshore mussel sample at a concentration of 0.015 mg/kg and tributyltin was detected in two of three samples at 0.036 mg/kg and 0.051 mg/kg). Of the butyltins, the only detected concentration was in the central portion of the site. Mussels were analyzed instead of clams for butyltins as a conservative indicator for assessing the presence of bioaccumulation effects of butyltins in biota.

*Inorganic Constituents in Clams:* Twenty-two (22) of the 24 inorganic constituents analyzed for presence in nearshore clams were detected. Approximately half of the maximum detected concentrations of inorganic constituents were observed in the eastern end of the site. As indicated above, nearshore clam samples were not analyzed for butyltins

.

*Semi-Volatile Organic Compounds in Mussels:* Of the 40 SVOCs analyzed for presence in mussels, 34 PAHs were detected including heterocyclic PAHs such as dibenzothiophenes. Most of the maximum detected concentrations of SVOCs were observed in nearshore (NS) sample NS-1/2. Thirty-one (31) of the PAHs detected in mussels were present in all three samples. The concentrations of PAHs detected in nearshore mussels ranged from 0.0013 mg/kg (dibenzo(a,h)anthracene) to 0.21 mg/kg (pyrene).

*Semi-Volatile Organic Compounds in Clams:* Of the 40 SVOCs analyzed for presence in nearshore clam samples, 35 were detected including 34 PAHs and one other constituent, dibenzofuran. Most of the maximum detected SVOC concentrations were observed near the central portion of the site. Thirty-two (32) of the detected PAHs were present in the three nearshore clam samples. The concentrations of PAHs detected in nearshore clams ranged from 0.0064 mg/kg (acenaphthylene) to 0.59 mg/kg (fluoranthene). Dibenzofuran was detected in two of three nearshore clam samples at concentrations of 0.015 to 0.017 mg/kg.

*PCBs in Mussels:* Aroclor-1254 was detected in the three nearshore mussel samples at concentrations of 0.25 to 0.31 mg/kg. The maximum detected concentration was observed in the eastern portion of the site.

*PCBs in Clams:* Aroclor-1254 was detected in the three nearshore clam samples at concentrations ranging from 0.024 to 0.066 mg/kg. The maximum detected concentration was observed in the eastern portion of the site.

<u>Offshore Shellfish Data</u>

Mussels were not observed at the offshore subtidal sampling locations. Inorganic constituents, SVOCs, and Aroclor-1254 were the most frequently detected analytes.

*Inorganic Constituents:* Twenty (20) of the 24 inorganic constituents analyzed for presence in offshore clam samples were detected. The greatest number of the maximum detected concentrations of inorganic constituents were observed offshore of the western portion of the site. The offshore clam samples were not analyzed for butyltins.

*Semi-Volatile Organic Compounds:* Of the 40 SVOCs analyzed for presence in offshore clam samples, 32 PAHs were detected. The PAHs detected included heterocyclic compounds such as the dibenzothiophenes. Most of the maximum detected concentrations of SVOCs were observed offshore near the eastern portion of the site. Twenty-one (21) of the detected PAHs were present in the three offshore clam samples. The concentrations of PAHs detected in offshore clams ranged from 0.00075 mg/kg (fluorene) to 0.076 mg/kg (fluoranthene).

*PCBs:* Aroclor-1254 was detected in the three offshore clam samples at concentrations ranging from 0.03 to 0.086 mg/kg. The maximum detected concentration of PCBs in clams was observed in samples offshore of the eastern portion of the site.

<u>Summary of Ground Water Data</u>

*Inorganic Constituents:* Of the 24 inorganic constituents analyzed for presence in ground water, 22 were detected.

*Volatile Organic Compounds:* Of the 34 VOCs analyzed for presence in ground water, one sample contained detectable levels of three constituents (carbon disulfide, chloroform, and methylene chloride at 0.001 to 0.040 mg/l). Although these compounds are often associated with laboratory contamination, the Appendix data provided in the TRC report did not flag these results as suspect.

*Semi-Volatile Organic Compounds:* Of the 66 SVOCs analyzed for presence in ground water, 18 were detected including 14 PAHs, three phthalates, and one additional constituent, dibenzofuran. The concentrations of PAHs detected in ground water range from 0.0006 milligrams per liter (mg/l) (naphthalene) to 0.044 mg/l (phenanthrene). The three phthalates detected in ground water include: bis(2-ethylhexyl)phthalate, diethylphthalate, and di-n-butylphthalate. The concentrations of these phthalates in ground water range from 5E-04 mg/l to 0.11 mg/l (bis(2-ethylhexyl)phthalate). Dibenzofuran was detected in one of 19 ground water samples at a concentration of 0.001 mg/l.

*PCBs and Pesticides:* PCBs were not detected in ground water. Of the 21 pesticides analyzed for presence in ground water, endrin was detected in one of 16 samples at a concentration of 5E-05 mg/l.

## 2.2 ASSESSMENT AND MEASUREMENT ENDPOINTS OF CONCERN, INCLUDING CONTAMINANTS AND SPECIES

### 2.2.1 Contaminants of Concern

Proposed Contaminants of Concern (CoCs) will be identified for this investigation using a rationale which links the source (Old Fire Fighting Training Area) to potential marine receptors in Coasters Harbor and Narragansett Bay through plausible exposure pathways. In this approach, frequency of detection, range of concentration, and elevation relative to minimum effects benchmarks (NOAA's ER-Ls) and background concentrations (metals only) are evaluated for chemicals detected in offshore media during prior investigations. This preliminary list of CoCs will be presented to the Ecorisk Advisory Board for review and comment. The final selection of CoCs for offshore exposure media will be made following completion of Exposure Assessment for the ERA (see Section 5.0 of this addendum) and regulatory review.

A preliminary CoC screen has been performed based on results presented in TRC (1994) and are summarized in Table C2-2. All analytes measured during the TRC survey would be included as CoCs.

### 2.2.2 Ecological Systems/Species/Receptors of Concern

The rationale for identifying ecological systems/species/receptors of concern (hereafter termed "receptor of concern") at Old Fire Fighting Training Area follows that provided in Section 2.0 of the Master Work Plan. Receptors of concern associated with the site which are potentially at risk include:

- nearshore habitats directly adjacent to past disposal areas;
- pelagic communities, including plankton and fish;
- infaunal benthic communities in sediment depositional areas;
- soft and hard bottom epibenthic communities; and
- commercially, recreational, and/or aesthetically important natural resource species.

This list leads to identification of target receptors of concern in this ecological risk assessment. Table C2-3 identifies target receptors of concern for Old Fire Fighting Training Area. The rationale for selection of these receptors includes:

- Blue mussel (*Mytilus edulis*) - This species is a locally abundant and ecologically important bivalve filter-feeder found in intertidal and subtidal habitats. It is an important food source for birds, fish, starfish, and occasionally humans. Blue mussels are surrogates for epi-benthic species in the intertidal environment that are potentially exposed to water-borne and particulate-bound contaminants. Blue mussels are also surrogates for pelagic species when deployed in the water column away from the seafloor.

- Mummichog (*Fundulus* spp.) - This species is a locally abundant and ecologically important estuarine fish species which feeds opportunistically upon both animals and plants. It is an important food source for birds and other fish. Mummichogs represent pelagic fish species that tend to inhabit vegetative and other sediment occurring areas and are thus potentially exposed to water-borne and bulk sediment contaminants.

- Cunner (*Tautogolabrus adspersus*) - This species is a locally abundant and ecologically important estuarine fish species which thrive in areas of topographic relief, e.g. docks, piers, rock piles large debris, etc., and feeds opportunistically upon both epibenthic animals and plants. Sediment often occurs in the gut through incidental ingestion. Hence, their exposure to CoC's likely arises from both food and water.

- Winter flounder (*Pseudopleuronectes americanus*) - This species is a locally abundant and ecologically and economically important fish species which feeds upon benthic organisms. It is an important food source for birds, other fish, and humans. Flounder represent demersal fish species potentially exposed to water-borne and bulk sediment contaminants. Present abundances of this species do not permit their collection.

- Lobster (*Homarus americanus*) - This species is a locally abundant and ecologically and economically important subtidal crustacean which feeds opportunistically as a scavenger. It likely is an important food source for fish and humans. Lobster represent epibenthic species potentially exposed to water-borne and bulk sediment contaminants.

- Hard clam (*Mercenaria mercenaria, Pitar morrhauna*) - These morphologically and ecologically similar subtidal bivalve filter-feeders are locally abundant and are ecologically and economically important. They are important food sources for birds and occasionally humans. Hard clams represent infaunal species potentially exposed to bulk sediment and pore water contaminants.

- Soft shell clam (*Mya arenaria*) - This species is locally abundant and an ecologically important intertidal bivalve filter- feeder. It is an important food source for birds and humans. Soft shell clams represent infaunal species potentially exposed to bulk sediment and pore water contaminants.

- Benthic community - The infaunal benthic community, including sponges, corals, mollusks, segmented worms, arthropods (including crustaceans), starfish, and chordates (tunicates and fish), is an ecologically important, potentially rich assemblage of species with diverse life histories and feeding strategies. It is an important food source for birds, fish, and benthic and epibenthic invertebrates. The benthic community is potentially exposed to bulk sediment and pore water contaminants.

- Great Blue Heron/Herring gull - These species are local avian aquatic predators which feed upon invertebrates and fish. The heron is a natural resource species of aesthetic importance and represents primarily a piscivorous feeding habit. Herring gulls are common to the area and display an omnivorous feeding habit. Impacts on these species will be assessed through food chain modeling with application of Toxicity Reference Values (TRVs) as agreed upon by the Ecorisk Advisory Board.

Plausible exposure pathways for each of these receptors are presented in Section 2.3 of this addendum.

### 2.2.3 Assessment and Measurement Endpoints

Based upon the preliminary considerations of stressors, their potential ecological effects, and ecosystems which may be at risk, and in keeping with the requirements of the RI/FS process, a suite of assessment endpoints were identified as being important in this assessment. As indicated in Table C2-4, these include the general quality of estuarine sediments and water, and the status of natural resource species.

Several measurement endpoints will therefore be employed at the Old Fire Fighting Training Area as indicators of the higher level ecological and societal values represented by the assessment endpoints (Table C2-4). The measurement endpoints have been selected based on:

- o Their relevance to the assessment endpoint and receptors of concern, and their relevance to expected modes of action and effects of CoCs;

- o Determination of adverse ecological effects;

- o The availability of practical methods for their evaluation; and

- o Their utility in extrapolations to other endpoints.

Most of these measurement endpoints have been used in other studies, and have proven to be informative indicators of ecological status in marine and estuarine systems with respect to the stressors identified as important in this assessment. Many serve a dual purpose in that they provide information relevant to two or more assessment endpoints.

In addition to the measurement endpoints used to evaluate the occurrence of, or potential for, adverse ecological effects, exposure point measurements will be employed to evaluate exposure conditions. Shown in Table C2-5, these exposure point measurements include chemistry measurements or estimations made in environmental media (water, sediment, pore water, biota), as well as geochemical attributes of exposure media which may influence the availability of contaminants to receptors.

The protocols and methods used to evaluate measurement endpoints and exposure measures are discussed in Section 4.0 of this addendum.

## 2.3 CONCEPTUAL MODEL

The Master Work Plan describes the first three tiers of the conceptual model developed to describe potential ecological risks associated with the Navy disposal sites in the lower Narragansett Bay. These initial three tiers describe the origin, transport and fate of stressors at different spatial and temporal scales. To complete this model, receptors and stressors specific to Old Fire Fighting Training Area are included in the fourth and final tier, which describes exposure pathways (from source to receptor) hypothesized for the site.

The first tier of the conceptual model (Figure 1-2 of Master Work Plan) describes the general north-to-south gradient in stressor concentration in Narragansett Bay. Although many sources contribute to this gradient, and local sources may influence specific stressor concentrations anywhere in Narragansett Bay, this model suggests that contaminant concentrations in the immediate vicinity of Old Fire Fighting Training Area should be evaluated within the context of the lower Bay to evaluate the extent and significance of this potential contaminant source on the ecology of Coasters Harbor and Narragansett Bay.

The second tier of the conceptual model (Fig. C2-2) describes the local release of contaminants from the Old Fire Fighting Training Area. Contaminants are hypothesized to be transported from onshore sources *via* surface and ground (seep) water routes, and from the harbor to Narragansett Bay through direct contact of Bay water with Coasters Harbor sediments. A localized gradient is expected in sediment contaminant concentration, with highest levels occurring in areas nearest to the source.

The third tier of the model (Fig. C2-3) provides details of the aquatic behavior of contaminants leading to exposure of ecological systems in Narragansett Bay, and aides in identification of potential adverse ecological effects. The general principles of contaminant behavior have been described in the Master Work Plan. As shown in Figure C2-3, bound contaminants may be transported in the water column in association with particles, but may also settle to the bottom in localized depositional areas, such as the harbor sediment as found in previous site investigations.

As described by the first three tiers of the conceptual model for NETC sites, including Old Fire Fighting Training Area, ecosystems potentially at risk include nearshore habitats, pelagic, benthic, and epibenthic communities, and natural resource species. The description of stressor dynamics suggests the potential of risks to these systems should be highest in areas of Coasters Harbor adjacent to the Old Fire Fighting Training Area. Although potential risks to other ecological systems present in the Narragansett Bay cannot be dismissed, this conceptual model focuses the assessment on ecosystems associated with depositional sediments in Coasters Harbor. Chemical stressors in these areas include the proposed CoCs identified in Table C2-2, as described in Section 2.2.1.

The fourth, final tier of the conceptual model for Old Fire Fighting Training Area describes hypothesized exposure pathways relating CoCs in the Harbor to the receptors of concern identified in Table C2-3. Developed for receptors by ecological habit (pelagic, epibenthic, infaunal, avian predator), these exposure pathways are illustrated in Figures C2-4 to C2-7. Illustrated in these figures are the routes of CoC transport from terrestrial sources, through intermediate sources (runoff, groundwater), to the proximal source of exposure and to receptors. These proximal sources become the exposure points in the Exposure Assessment. Also illustrated are the measurement endpoints which will be evaluated in the Ecological Effects Assessment.

## 3.0 Identification of Data Needs

Data needs for the ERA are those which represent information necessary to support the characterization of species and contaminants of concern (Site Characterization), transport and receptor pathways (Exposure Assessment), and the potential offshore ecological impacts related to Old Fire Fighting Training Area (Ecological Effects Assessment).

The sampling proposed in this addendum is necessary for several reasons: 1) organic and metal sediment contaminants, pore water metals and SEM/AVS studies need to be conducted in conjunction with toxicity studies to assess the potential toxic effects of contaminated sediments on the biota; 2) contaminant studies need to be conducted in conjunction with biological indicators to assess the potential impact of contaminated sediments on individual species and the benthic community structure, and 3) geophysical and hydrographic surveys are needed to determine the spatial (both horizontal and vertical) distribution of sediment types and to determine the circulation pattern and strength of the area, so as to elucidate the pathways of contaminant movement and the potential for resuspension of contaminated sediment.

## 3.1. CONTAMINANT DATA NEEDS

*Sediment Chemical Analyses.* Determination of the concentrations of selected metals, PCB congeners, pesticides, PAHs and butyltins from limited surface and core sediment samples is required to further document magnitude and extent of contamination, including the elucidation of vertical contamination gradients. In addition, the bioavailability of contaminants must be considered, thus measurements of total organic carbon for understanding bioavailability of non-ionic organic contaminants and SEM/AVS for metal bioavailability are critical and will be determined for sediments. Interstitial (pore) water metals are measured in surface sediment extracts to gain a clearer picture of true metals exposure within the inhabited zone for infaunal and epibenthic invertebrates.

*Tissue Chemical Analyses.* Tissue analyses are needed for the same suite of analyses as performed in sediments. Data are needed on both non-depurated and depurated bivalves in order to assess the importance of gut contents in discerning chemical exposure and pathways for contaminant transfer in the food chain. Similarly, fish tissue data are required to assess contaminant bioavailability for species with differing trophic modes and feeding/habitat preferences. Tissue-specific lobster data are desired to discern food chain transfer potential due to food consumption preferences by humans. Lipid content data are needed for all tissue samples to assist in the intercomparison of organic contaminant residue data between species and over time.

*Geotechnical characteristics.* The grain size distribution of surface and core samples is required to better understand habitat differences among sites, and as a correlate to TOC and AVS, to assess the relative binding capacity and potential contaminant content of sediments. The data are also used to interpret the results of remote sensing methods for habitat characterization such as side scan sonar, where acoustic reflection strength (side scan image whiteness) is proportional to grain size, thus allowing one to map sediment type from spatial variation in the image.

## 3.2. BIOLOGICAL DATA NEEDS

*Toxicity Testing.* Toxicity tests are essential tools to evaluate the bioavailability and toxicity of contaminants in bulk sediment and pore water, and hence provide key data in the Ecological Effects component of the ERA. The proposed tests, including the amphipod 10-day acute test and the sea urchin fertilization test, are widely used and standardized procedures for this purpose.

*Condition Indices.* Condition indices data are needed to determine whether site-related exposures have resulted in physiological impairment (e.g. reduced growth) or disease (e.g. fin rot) of indigenous populations. Similarly, estimates of abundance, and distribution of the large bivalves within the study area are needed to assess the potential for population-scale impacts on these ecologically, recreational, and economically important group of organisms.

*Benthic Community Structure Analyses.* Benthic community structure analyses focus on the smaller invertebrate population and are needed to evaluate impacts of physical and/or chemical insult on the stability and diversity of indigenous populations. Given that communities represent a higher level of organization than the species, this analysis is needed to augment results obtained from toxicity analysis. Identification to species is needed to calculate diversity measures, identify indicators, and compare results with previous studies.

Previous studies of the benthic community structure (TRC, 1994) have been undertaken in the Old Fire Fighting Training Area, but were of limited spatial distribution (2 stations), hence the proposed survey will rectify this significant data gap. This survey is also needed to provide information on the potential role of bottom animals in the sedimentation, erosion, and vertical mixing of contaminated sediments, as well as to identify the primary organisms in the food chain through which pollutants may be transferred.

*Mussel Deployment.* Chemical residues and growth data from deployed mussels (*Mytilus edulis*) are needed to characterize water column exposure conditions and evaluate potential ecological effects for pelagic species. In addition, supporting water measurements of temperature, salinity, dissolved oxygen, suspended solids and chlorophyll a concentration are needed at weekly intervals during the mussel deployments to provide background data on the environmental conditions under which bioaccumulation and growth are occurring.

*Analyses for Fecal Pollution Indicators.* Sewage is known to contain concentrated numbers of potential microbial pathogens. Even after rigorous treatment, sewage discharges may still harbor numerous resistant microorganisms. The proximity of the Newport sewage treatment plant outfall on Coddington Point, as well as the proximity of several streams, runoff culverts, and outfalls in and around the Old Fire Fighting Training Area, support the possibility that potential pathogens associated with fecal pollution could be a direct stressor to species related to the site, or indirectly through the food chain. Limited data on the above biological indicators are available from previous studies within Coasters Harbor, hence a survey will be conducted to examine sediment and marine animal tissue quality to fill a significant data gap.

### 3.3. HYDROGRAPHIC AND GEOPHYSICAL DATA NEEDS

*Dissolved oxygen and ammonia concentration.* Dissolved oxygen and ammonia concentration are two water column parameters for which marine organisms have minimum fluctuation tolerances. Dissolved oxygen (DO) concentrations below 2-3 ppm are considered hypoxic, and can adversely impact a species physiology. Free-ammonia ($NH_4$) is highly toxic to marine organisms and may reach significant concentrations above the sediment water interface during hypoxic conditions. Data on these parameters are highly desirable for Coasters Harbor where communities may be affected by episodes of hypoxia which occur because of restricted circulation in the harbor as well as added biological oxygen demand caused by nutrient loading. These data are also needed as companion data for similar measurements made in test chambers during toxicity tests.

*Hydrographic studies of Coasters Harbor.* Characterization of both the magnitude and patterns of flow within the Coasters Harbor region are required to discriminate between contaminant transport pathways to receptors resulting from exposure to off-site sources vs. site-related sources. In addition, the magnitude of contamination already observed in Coasters Harbor suggests that significant hot-spots of contamination exist which may be related to differential circulation and/or residence time (flushing rates) characteristics within various sections of the harbor. The model of circulation to be developed from this work is also needed to predict the redistribution and flux of contamination out of the harbor which might occur under varying hydrographic conditions (e.g. storms) and/or remediation actions.

*Geophysical Survey.* The geophysical survey is needed to map the surficial distribution of sediment type such that the station-specific chemistry and toxicity results may be generalized to the entire study area. In addition, the sub-bottom profiling component will provide a third dimension to sediment distribution which could be used, in conjunction with contaminant data, to estimate the volume (if any) of contaminated sediment that may require remedial action.

## 4.0 PLAN FOR DATA COLLECTION AND ANALYSIS (FIELD SAMPLING AND ANALYSIS PLAN)

The primary purpose of the proposed data collection and analysis activities are to fill data gaps in the information base required to complete the ecological risk assessment. In the following sections, station locations, and plans for collection of sediments, biota and hydrographic/geophysical data are presented, as well as a general description of the methods and QA/QC procedures used in the sample and data analysis. A complete description of the methods and QA/QC procedures for sediments and biota are contained in the Master Work Plan.

## 4.1. STATION LOCATIONS AND SAMPLING METHODS

### 4.1.1. Sediment Sampling Plan

The locations of the proposed sampling stations in OFFTA are shown in Figure C4-1. A total of 21 stations have been selected. The stations have been selected to confirm previous results of high concentrations of contaminants, to fill data gaps from prior studies, and to characterize the offshore gradient in contaminant concentrations. The Coasters Harbor channel and accompanying circulation are highly unique to the study area. An exhaustive search of the region failed to locate comparable habitat other than that found around Coasters Harbor itself. Because these features have profound influence on sediment characteristics and benthic community structure, it was determined that a reference location in this region would better serve to represent baseline, non-impacted biological conditions than would other locations with dissimilar hydrographic characteristics. Hence, reference collections for inshore and offshore sediments and organisms will be attempted in an area of southeastern Coasters Harbor (SCH) as shown in Figure C1-1. This area is approximately 1.2 km south of OFFTA, and is adjacent to marina activities as are the OFFTA sampling sites discussed below. Chemical data from this site will be evaluated against other reference locations (e.g. Potter Cove, SAIC/URI 1995) to determine whether chemical exposures occurring at the SCH reference site are comparable to background conditions for the region. Hydrographic conditions will also be evaluated to assess the direction of net current flow between the site and reference locations so as to determine the potential extent of site influence on chemical composition of reference sediments.

A sample collection and laboratory analysis summary for the OFFTA ERA is shown in Table C4-1; a base map for station locations is shown in Figure C4-1. Twenty one stations at the north end of Coasters Harbor Island have been selected for chemical and biological sampling, and consist of intertidal (Stations 1-7), subtidal near-field (Stations 8-12), mid-field (Stations 14-18) and far-field (Stations 13, 19, 20, and 21) station locations These station locations have been selected to detect an environmental gradient from potentially contaminated intertidal and near-field stations to presumably less contaminated far-field stations, while also sampling the ecological gradient in biotic composition along the concordant depth gradient.

Surface grabs will be collected at all twenty one stations shown in Figure C4-2 and at the reference stations, and will be analyzed for bulk sediment and elutriate chemistry (metals and organics), toxicity (amphipod survival, sea urchin larval development), SEM/AVS, grain size, total organic carbon (TOC), and benthic community composition (enumerated to species).

At each station, surficial sediment (0-15 cm) from an undisturbed grab sample is collected. Approximately 2-3 Van Veen or 3-5 Smith-MacIntyre grabs are needed to collect sufficient sample for both chemistry and toxicity analyses. The material from each grab is composited in a 12-liter polyethylene bucket, homogenized with a titanium stirrer for ~30 seconds, and then subsampled into precleaned containers for organic and inorganic chemistry, SEM/AVS analyses and toxicity studies. The samples are then stored on blue ice during collection and at -20°C upon return to the laboratory. The grab sampler will be "washed-down" with sea water between grabs. Between stations, the sampling apparatus is rinsed in sequence with distilled water, 1:1 nitric acid, methanol and de-ionized water. Field-rinsed blanks of the scoop water will be collected and analyzed. Additional box core samples will be obtained at each station and reference locations and used for benthic infaunal analysis. Two (2) 400 $cm^2$ Van Veen grab samples will be obtained and sieved back at the laboratory to 0.5 mm. Organisms will be picked from the screen and preserved for taxonomic analyses.

Two additional samples will be taken at depth for a subset of the above stations using traditional hand-held coring techniques. A standard piston corer, the biological corer, is used to retrieve cores from shallow areas such as Coasters Harbor (e.g. water depth <20 m). This corer uses polycarbonate tubes and is deployed using a series of 3 meter long extension rods to push the corer into the sediment. Cores of up to one meter long are recovered using this design. The cores are transported in the vertical position to the lab for storage at 4°C until logging and sectioning. Sectioning is completed within 48 hours of collection. Sectioned sediment samples are stored at -20°C until chemical analysis. Cores will be taken to a depth of 1 meter or refusal at stations 4, 5, 6, 10, 11 and 18 (Figure C4-3). These stations were selected primarily to target the region of high contamination found in the TRC (1994) study. The combination of surface and subsurface chemistry data at these core stations will provide estimates of the depth of contamination near OFFTA.

#### 4.1.2. Biota Sampling Plan

The proposed biota sampling summary for Old Fire Fighting Training Area are summarized in Table C4-1. It will be necessary to maintain flexibility in this plan because the actual distribution of available organisms within Coasters Harbor is not well known. Target species at the intertidal stations (Stations 1-7) are the soft shell clam (*Mya arenaria*) , blue mussel (*Mytilus edulis*) and mummichog (*Fundulus* spp)/cunner (*Tautogolabrus adspersus*), representing infaunal, epifaunal and pelagic exposure pathways, respectively (Figure C4-4). The infaunal target species at the subitdal near-field, mid-field and far-field stations will be hard clam species (*Mercenaria mercenaria* or *Pitar morrhauna*; Figure C4-5). Sampling locations may be adjusted if repeated attempts fail to produce required numbers for chemical analyses.

Target species for epifaunal and pelagic exposure pathway assessments at far-field stations include epibenthic (lobster) and pelagic (deployed blue mussel) indicator species (Figure C4-6). Lobsters are collected by baited trap and typically require an extended sampling effort with compositing of resected muscle until sufficient biomass is reached for chemical analysis. As with other biota collections, relocation of station position may be required if best efforts fail to collect adequate species numbers for analytical requirements.

Mussels are used as indicators of pelagic water column conditions when deployed off the bottom in cages. Mussel deployments will also occur at the subtidal reference station. Depending on seasonal timing, the deployment will last from 6 to 8 weeks. An apparatus consisting of moorings, anchor weights, and four mussel cages will be deployed at seven stations within the study area. Data will be collected on chemical residue levels and individual growth rate as shell length; in addition, analysis for potential pathogen indicators in tissues will be conducted to determine if potential exposure to fecal pollution is occurring which might be related to sources near the Old Fire Fighting Training Area or sources outside Coasters Harbor.

### 4.1.3. Geophysical/Hydrographic sampling plan

The work described in this section details the approach necessary to spatially characterize sediment distribution, as well as determine the water circulation pattern near the Old Fire Fighting Training Area and adjacent Coasters Harbor, including the exchange between Coasters Harbor and Narragansett Bay.

*Geophysical Surveys* The survey will utilize a composite Datasonics Chirp Sub-bottom Sonar and Side-Scan Sonar system that was used for McAllister Point. Side scan sonar will be used for surface characterization; chirp sonar will be used to determine depth of sediment units. The proposed study area is shown in Figure C4-7. This area includes Coasters Harbor, and a small area outside the mouth of Coasters Harbor up to the Newport Sewage Treatment Plant outfall. The inner harbor area has been excluded because of water depth limitations. The side-scan/chirp probe will be towed behind a vessel along pre-designated survey lines spaced approximately 20-50 m apart. This survey strategy is intended to provide >90% bottom coverage of the survey area. Navigation will be provided at Differential Global Positioning System (DGPS) accuracy (resolution to $\pm$3 m).

*Hydrographic Surveys.* The hydrographic survey plan is shown in Figure C4-8. Data on current velocity vs. depth will be collected in real time using a moving platform with an RD Instruments Broadbeam $1200_{TM}$ acoustic Doppler current profiler (ADCP), which can vertically profile water currents from a moving platform to a $\pm$ 5 cm sec$^{-1}$ accuracy. Factors to be considered in the hydrographic survey include the pattern of water circulation driven by semi-diurnal tides and longer-term, non-tidal net flow driven by winds and density variations. Energetics and flow patterns within Coasters Harbor will be determined from data collected over a gridwork of survey lines. The approximate time required to complete the designated line series survey within the Harbor is between and hour and an hour and a half per full cycle.

This survey strategy and instrumentation has been used successfully in a previous study of circulation within the Housatonic River Estuary in Connecticut. The use of the ADCP data eliminates inaccuracies in extrapolating three dimensional circulation patterns from point velocity current meters and allows for a rapid, accurate and highly cost-effective measurement technique for elucidating circulation patterns inside and in the immediate vicinity of Coasters Harbor.

To determine the effect of tidal variation during the survey and remove its effect from the data interpretation, a pressure (tide)/conductivity/temperature gauge will be deployed at the mouth of Coasters Harbor. A number of conductivity, temperature and depth (CTD) surveys will also be conducted to determine water density distributions and salt fluxes across the relevant interfaces.

Three data collection surveys will be conducted to characterize the following: 1) spring or high runoff conditions which will include a Spring tide, 2) late summer or low flow conditions and 3) late fall conditions when seasonal cooling effects become important. The first two sampling sets are most important for characterizing periods of maximum and minimum kinetic/mixing energies, respectively. Finally, information on the kinetic energy of the tidal flow and circulation patterns will be combined with data on sediment size distributions and empirical laws to estimate sediment resuspension and transport patterns in the Coasters Harbor - Narragansett Bay system.

## 4.2. SAMPLE ANALYSIS PLAN

Detailed descriptions of Standard Operating Procedures (SOPs) and Quality Assurance/Quality Control (QA/QC) procedures to be used for chemical and toxicological analyses of sediments and biota are contained in Appendices A and B of the Master Work Plan, respectively. The following section reviews general aspects of these procedures, and describes site-specific modifications/additions where necessary.

### 4.2.1. Chemical Analyses

*Sediments.* The concentrations of selected metals, PCB congeners, pesticides, PAHs and butyltins will be determined from surface and core sediment samples (refer to Table 3-2 of Master Work Plan). Two depths per core sample will be analyzed, such that the complete analysis suite will consist of three vertical measurements (surface + 2 depths). These data will serve as the basis from which vertical contamination gradients will be discerned. In addition, the simultaneously extracted metals (SEM) and the acid volatile sulfide (AVS), and the ratio (SEM/AVS) will be determined for sediments.

*Tissues.* Tissue analyses will include the same suite of analyses as determined in sediments. Shell and exoskeletal material will not be analyzed for any species. Bivalve and fish tissue will be frozen whole after collection and analyzed whole. Samples of bivalves from the collection will be selected at random and will be shucked at the organic or inorganic lab depending on the analysis. Lobster specimens will be resected immediately following euthenization to obtain separate tissue groups; muscle, hepatopancreas, and reproductive material ("tamali"). In addition, the lipid content of the tissue will be determined and used in bioaccumulation factor calculations.

*Pore Water.* Interstitial (pore) water metals will be measured in surface sediment samples utilizing the vacuum extraction method. Duplicate sample preparations are made for pore water toxicity and metals analyses. Approximately 100 ml of pore water can be obtained from sediment held at 4°C in a 24 h period.

*Whole water samples.* During the sample collection period, and during the hydrographic study, whole water samples will be collected at several stations in Coasters Harbor. Water will be collected with a Go-flo or Niskin bottle, preserved and analyzed for dissolved oxygen and free ammonia concentration. The whole water samples will be used to calibrate the CTD profiles and the ammonium sensor incorporated into the CTD profiler. Methods for these analyses are described in Appendix C of the Master Work Plan.

### 4.2.2. Geotechnical Analyses

*Grain size.* The grain size distribution and total organic content of the surface and core samples will be determined as described in Appendix B of the Master Work Plan. The grain size data will be used to ground-truth the side-scan sonar map and to normalize the metals data for lithologic variation.

*Total organic content.* The total organic content data will be used to normalize the organic contaminant data. These measurements are critical to assess organic contaminant bioavailability and equilibrium between sediment and porewater.

*Magnetic Susceptibility.* Magnetic susceptibility will be measured at a 3 cm interval downcore on the 6 piston cores. The profiles of susceptibility will be analyzed to correlate the depositional histories of cores and will be used to select age-comparable depths across cores from different stations for sectioning and further chemical analyses.

### 4.2.3. Biological Assays

*Toxicity Testing.* All surface grab samples will be evaluated for bulk sediment and pore water toxicity using the amphipod 10-day acute test and the sea urchin fertilization test, respectively. A complete description of these test methods are contained in the Master Work Plan.

*Condition Indices.* Condition indices for bivalves will be determined from the ratio of dry tissue weight to shell length, weight and volume. Fish and lobsters will be inspected for external evidence of pathological damage (fin rot, gill lesions, shell disease, *etc.*); statistical analyses for differences in condition among stations and reference stations will be conducted using station grouping as replicate data. Soft shell clams will be assayed for the presence of hematopoeitic neoplasia, a blood cell disorder correlated with contaminant exposure (Munns et al., 1991).

*Benthic Community Structure Analyses.* Quantitative analyses for benthic community structure will employ sample processing and counting techniques, closely following those used in the EPA EMAP program and in the benthic infauna survey of McAllister Point carried out by Menzie - Cura & Associates in August 1993. Organisms will be identified and counted to species. From the data obtained, community structure parameters including species richness, evenness and the number of opportunistic forms present will be calculated.

Benthic community structure data obtained from stations adjacent to the Old Fire Fighting Training Area will be compared against reference area results, as well as with historical data obtained from stations in lower Narragansett Bay and other estuaries in the region. To aid in the interpretation of data, information from side-scan sonar and diver observations will be used for the identification of the bottom characteristics corresponding to the location from where the benthic community data was obtained.

*Fecal Pollution Indicators.* Total and fecal coliforms (including *E. coli*), fecal streptococci and enterococci as well as *Clostridium perfringens* spores are enumerated in deployed mussel tissue using the most probable number method. Application of indicator-specific media and incubation temperatures to this standard FDA tube method allow for the rapid detection and enumeration of each of the aforementioned indicator microorganisms.

### 4.2.4 Geophysical/Hydrographic Studies

*Geophysical Surveys.* Side scan sonar data can be processed to develop a 2-dimensional (2-D) mosaic picture of the seafloor similar to that generated for the McAllister Point area. Using this data, and incorporating data from the sub-bottom profiler, a 3-D map of sediment volume by type can be developed. In conjunction with sediment chemistry and toxicity data, the geophysical survey results can be presented in a format amenable to the estimation of the volume (if any) of contaminated sediment that may require remedial action.

*Hydrographic Studies*. The CTD and Broadband ADCP survey data will be analyzed to characterize seasonal water density and flow patterns in Coasters Harbor and from the Harbor into neighboring portions of Narragansett Bay. The spring and summer data sets will be used to characterize the maximum and minimum periods of current strength and turbulent mixing, respectively. Event scale perturbations, such as storms, will be documented. Supporting data for locations outside the study area will be used to place this site-specific information into a regional hydrographic context. These data sources will include (i) local wind and tide data from a recording station funded by the Office of Naval Research (ONR), which is currently being installed on the Graduate School of Oceanography (GSO) pier, and (ii) U.S. Geological Survey (USGS) river runoff data for Providence and Taunton Rivers.

### 4.3. SAMPLING LOGISTICS

Sampling will be conducted from research vessels as well as from shore. For relatively shallow stations (< 3 meters of water), a 7 meter pontoon boat and a 6 meter support motorboat owned by the Graduate School of Oceanography, URI, will be used for sampling. During the duration of the sampling, the research vessels will be moored at the Navy facilities in Newport or Coasters Harbor.

## 5.0 EXPOSURE ASSESSMENT

Exposure assessment for the Old Fire Fighting Training Area investigation will involve an evaluation of the site-specific conceptual model with respect to hypothesized exposure pathways. For this assessment, the Old Fire Fighting Training Area is considered to be the primary (but not proximal) source of CoCs in nearshore areas. Exposure Assessment will include direct measurement of exposure point concentrations along these pathways. Following the procedures identified in Section 4.0, proposed CoCs and possibly other chemical contaminants will be quantified in environmental media representing proximal sources (including biota). In addition to direct measurement of chemistry, other exposure measures (identified in Table C2-5) will be assessed to aid in the interpretation of chemical exposure conditions. Methods and QA/QC considerations and protocols relevant to analytical chemistry are presented in the master Work Plan and in Section 4.0 above.

Exposure information derived from previous investigations at the site will be evaluated for applicability to this assessment, and will be used as appropriate. Accompanying the use of these data will be a discussion of the comparability of the various data sets. Exposure Assessment for Old Fire Fighting Training Area will include evaluation of the uncertainty associated with the exposure analyses.

## 6.0 Ecological Effects Assessment

Ecological effects are quantified by determining the relationships between relevant exposure patterns and resulting responses of ecological systems, in terms of the measurement endpoints identified during Problem Formulation (Section 2). Four primary Ecological Effects Assessment activities will occur in the Old Fire Fighting Training Area investigation:

- site-specific toxicity evaluations of bulk sediments using the 10-day amphipod mortality test, and of elutriate waters using the sea urchin sperm cell test;

- site-specific evaluations of abundance and condition of the receptors identified in Table C2-3;

- review of available information regarding the known effects of CoCs;

- search and identification of applicable criteria and standards appropriate to the exposure media representing proximal sources along each exposure pathway;

Generally, quantification of measurement endpoints will coincide with quantification of exposure points concentrations of CoCs from a spatial perspective (see Section 4.0 above). An analysis of uncertainties associated with these activities will be included in the Ecological Effects Assessment for Old Fire Fighting Training Area.

## 7.0 Risk Characterization

A weight-of-evidence approach will be used as the primary method for characterizing offshore ecological risks associated with Old Fire Fighting Training Area. Several lines of evidence will be evaluated in drawing conclusions concerning risk:

1. *Analysis of CoC concentration versus observed adverse effects.* Analyses will be conducted to evaluate the relationships observed between measured CoC concentration and the quantified response of the measurement endpoint. For instance, if a particular CoC is causative in ecological impacts to a particular receptor, then a change in the response of measurement endpoints associated with that receptor should be observed with increasing CoC exposure. Interpretation of these patterns will involve a discussion of whether the observed ecological effect is expected to result from elevated exposure to the CoC.

2. *Analysis of bioaccumulation.* Elevated tissue residues in receptor species identified in Table C2-3 will be interpreted as an indication that CoCs are bioavailable and can potentially be transferred to other receptors through trophic interaction. Trophic transfer of CoCs to winter flounder and to avian predators will be calculated, as direct measurement of bioaccumulation in these species will not be made. Analysis of bioaccumulation in lobster will include two scenarios: one assuming a resident population, and the other assuming a migratory population. Information will be sought from the literature and will be used to estimate ecological risks to receptor species resulting from the presence of CoCs in tissues.

3. *Analysis of toxicity evaluations versus observed ecological effects.* Results of toxicity tests conducted on sediments and elutriate water from sampling stations will be compared with measurement endpoint response at those stations. Care will be taken to ensure that toxicity endpoint-measurement endpoint comparisons are appropriate for a particular receptor.

4. *Comparison of exposure point concentration with toxicity-based criteria and standards.* This analysis will involve calculation of exposure media-specific HQs and HIs using NOAA ER-Ls and ER-Ms for sediments, and ambient water quality criteria for pore waters. Crustal weathering models will be employed to evaluate CoC elevation relative to background conditions. SEM/AVS ratios for divalent metals, and pore water equilibrium partitioning for nonionic organic contaminants, will be employed to assess availability of CoCs to ecological receptors.

5. *Comparison of exposure point concentration with toxicity data.* Based on the known adverse effects of CoCs as reported in the literature and in toxicity data bases (*e.g.*, AQUIRE), the concentrations of CoCs measured at critical exposure points will be evaluated against suspected effects levels.

This weight-of-evidence approach will be used to evaluate causal relationships between CoCs (exposure) and the existence or suggestion of adverse ecological effects. For example, the observation of anomalies in benthic community structure in areas with SEM/AVS ratios greater than 1.0, but low organic CoC levels, would suggest divalent metals to be posing ecological risk in those areas. Observation of toxicity of bulk sediments collected in those areas would further support this hypothesis. Conversely, benthic community structure anomalies in the absence of elevated CoCs and sediment toxicity may implicate other types of stress, such as physical disturbance or low near-bottom dissolved oxygen. All available evidence will be utilized in evaluating the lines of evidence relating CoC exposure to potential adverse ecological effects. It should be noted that not all lines of evidence need point to one (or more) CoC as causative agents for risk to be presumed in association with that specific CoC(s). In this weight-of-evidence approach, it will only be necessary to have the preponderance of evidence suggest a causal relation in CoC-receptor pairings for risk to be concluded.

The uncertainties associated with risk characterization activities, and therefore with the entire site-specific ecological risk assessment, will be discussed and quantified (if possible) when investigation results are reported. These discussions will include identification of assumptions used, any remaining data gaps, and the limitations of the assessment. In addition, reference station data will also be used in qualitative discussions of the risk characterization results.

## 8.0 PROJECT ORGANIZATION AND RESPONSIBILITY

### 8.1 PROJECT MANAGERS

Mr. Stephen Parker, Brown and Root Environmental, will be the CLEAN Project Manager and will have primary responsibility for implementing and managing the ecological risk assessment. The Brown and Root Environmental project manager will also be responsible for notifying the Navy and regulatory agencies of field activities or modifications of project tasks.

Dr. James Quinn, Professor of Oceanography, University of Rhode Island, and Dr. Gregory Tracey, SAIC, will be subcontract Project Managers for this project. Drs. Quinn and Tracey have general management and QA/QC oversight of chemistry and biological risk characterization activities, respectively, under separate B&R Environmental subcontracts to URI and SAIC. In this capacity, they will conduct the following activities:

- Review progress of technical activities towards attainment of project goals;
- Review technical products and deliverables for quality and conformance to technical objectives of the project;
- Participate in project technical activities to the extent warranted by skills and task requirements;
- Communicate with B&R Environmental on issues relating to definition and conduct of project tasks, inform the B&R Environmental Project Manager of project status, and ensure the transmission of all deliverables to the B&R Environmental Project Manager in a timely manner;

- Ensure that the project is appropriately organized with effective lines of communication, and that project responsibilities and authorities for making critical decisions are clearly understood.

## 8.2 PROJECT QUALITY ASSURANCE OFFICER

The Project Quality Assurance Officer, Dr. Harry McCarty (SAIC), will be responsible for ensuring compliance to all project QA/QC objectives, and for communicating compliance status. He will perform the following specific tasks:

- Provide guidance in the preparation of the Work/Quality Assurance Project Plan (W/QAPjP);
- Perform technical review of the W/QAPjP and ensure that project QA/QC procedures are adequate for meeting data quality objectives;
- Conduct performance and systems audits to ensure compliance with project QA/QC procedures;
- Identify and report QA/QC deficiencies;
- Recommend appropriate corrective actions when a QA/QC deficiency is identified, and ensure that corrective measures are implemented effectively;
- Review and approve all products and deliverables of the project;
- Review documentation of all QA/QC activities that occur throughout the period of performance of this project.

## 8.3 PROJECT PRINCIPAL INVESTIGATORS

The Principal Investigators for this project have been selected for participation in this project based upon a number of criteria, including technical skill, experience, and existing commitments to other projects. Their responsibilities include oversight of all scientific activities in support of objectives of the project, conformance to all QA/QC requirements, and communication with the other Principal Investigators on issues of technical effort status, progress, and problems. Principal Investigators also will be responsible for communicating options regarding technical approach within their area of expertise. The Principal Investigators associated with this project are:

- Dr. James Quinn, Professor of Oceanography, University of Rhode Island. Dr Quinn's expertise is the biogeochemistry of organic compounds in the nearshore marine environment. Dr. Quinn will be responsible for the organic contaminant analysis of samples.

- Dr. John King, Associate Professor of Oceanography, University of Rhode Island. Dr King's expertise is the geochemistry of marine and estuarine sediments. Dr. King will be responsible for project planning and reporting, trace metals analyses, and geotechnical characterizations of sediments.

- Dr. Gregory Tracey, Senior Scientist in SAIC's Environmental Assessment Division. Dr.Tracey is experienced in environmental assessments, marine surveys, and ecological risk assessments. Dr. Tracey will be SAIC's Project Manager for the Old Fire Fighting Training Area offshore ecological risk assessment, and will be responsible for project planning, toxicological assessments, field sampling, Geographic Information System (GIS) interpretation, and ecological risk synthesis.

## 8.4 TECHNICAL COORDINATOR

Mr. Brad Wheeler, NETC Newport, will serve as the Navy's Technical Coordinator for this project.

## 8.5 NARRAGANSETT BAY ECORISK ADVISORY GROUP

Peer review is critical to the success of an ecological risk assessment project. Input from scientific experts, regulatory agencies, resource trustees, special interest groups, and the general public is important to ensure that project activities are designed to meet the scientific, regulatory, and societal needs of the assessment. In recognition of this, the Narragansett Bay Ecorisk Advisory Board will be established to solicit scientific input for conducting the site specific ecological risk assessments. They will meet periodically to provide technical input and assistance to the Navy for development of work plans, review of preliminary investigative results and the comprehensive ERA report for the site, clarification of regulatory issues, and to evaluate selected remedies in the context of economic benefit and habitat quality. The organizations and members of the Board include:

- U.S. EPA Region I - Kymberlee Keckler, Susan Svirsky;

- RI Department of Environmental Management - Paul Kulpa, Christopher Deacutis, Bob Richardson;
- NOAA - Kenneth Finkelstein;
- U.S. Fish and Wildlife - Tim Prior;
- NETC Newport - Brad Wheeler;
- Northern Division - Shannon Behr, Simeon Hahn;

The Navy has established the Narragansett Bay Ecorisk Advisory Board within a time frame suitable for review and comment upon the approach described in this document. Actual membership may vary over time.

## 9.0 REFERENCES


Battelle Ocean Sciences, 1994. Off-shore investigation of the Site 01 – McAllister Point Landfill, Site 02- Melville North Landfill, Site 09 – Old Fire Fighting Area at the Naval Education and Training Center (NETC) Newport, Rhode Island: Assessment of Chemical Contamination. Battelle Ocean Sciences, 397 Washington Street, Duxbury, MA 02332.

Long, E.R., D.D. MacDonald, S.L. Smith and F.D. Calder. 1995. Incidence of Adverse Biological Effects Within Ranges of Chemical Concentrations in Marine and Estuarine Sediments. Environmental Management 19(1):81-97

Menzie-Cura & Associates, Inc., 1994. Assessment of Marine Benthic Infauna & Epifauna in Vicinity of Naval Education and Training Center sites. Prepared for TRC Environmental Corporation.

Munns, W.R., Jr., C.A. Muller, D.J. Cobb, T.R. Gleason, G.G. Pesch and R.K. Johnson. 1991. Marine Ecological Risk Assessment At Naval Construction Battalion Center, Davisville, RI. Phase I. NOS Technical Report 1437, San Diego, CA pp. 237.

TRC Environmental Corporation (TRC), 1991. Phase I, Remedial Investigation Report, Prepared for Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania.

TRC Environmental Corporation (TRC), 1994. Draft Final Old Fire Fighting Training Area Remedial Investigation Report, Prepared for Northern Division, Naval Facilities Engineering Command, Lester, Pennsylvania. August.

University of Rhode Island (URI) and Science Applications International Corporation (SAIC), 1995. Narragansett Bay Ecorisk and Monitoring for Navy Sites, Final Work/Quality Assurance Project Plan. Prepared for Halliburton NUS Corp., 28 July 1995, 57 pp, 3 appendices and 4 addenda.

Figure C1-1. Study and reference site locations for the Old Fire Fighting Training Area Ecological Risk Assessment.

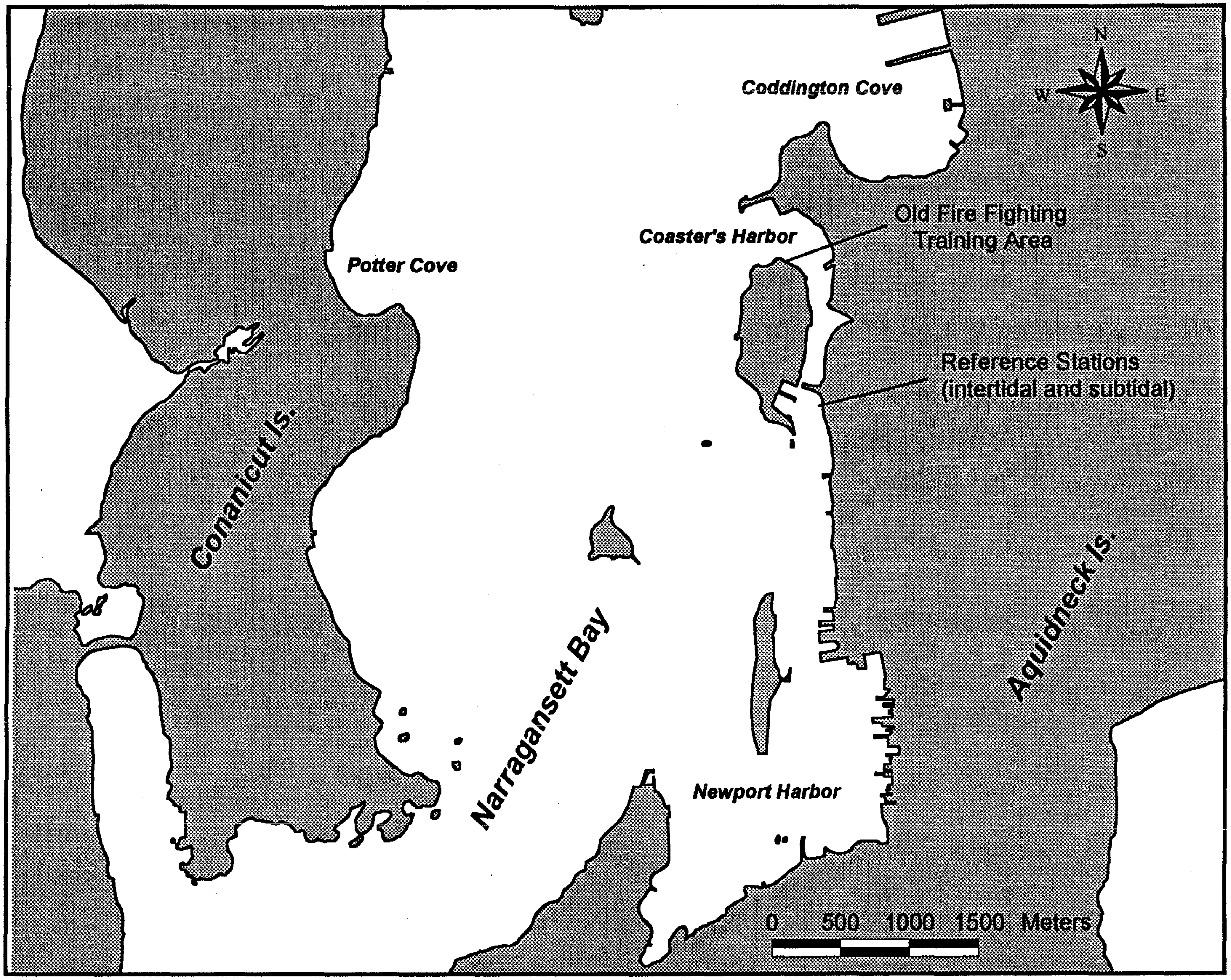
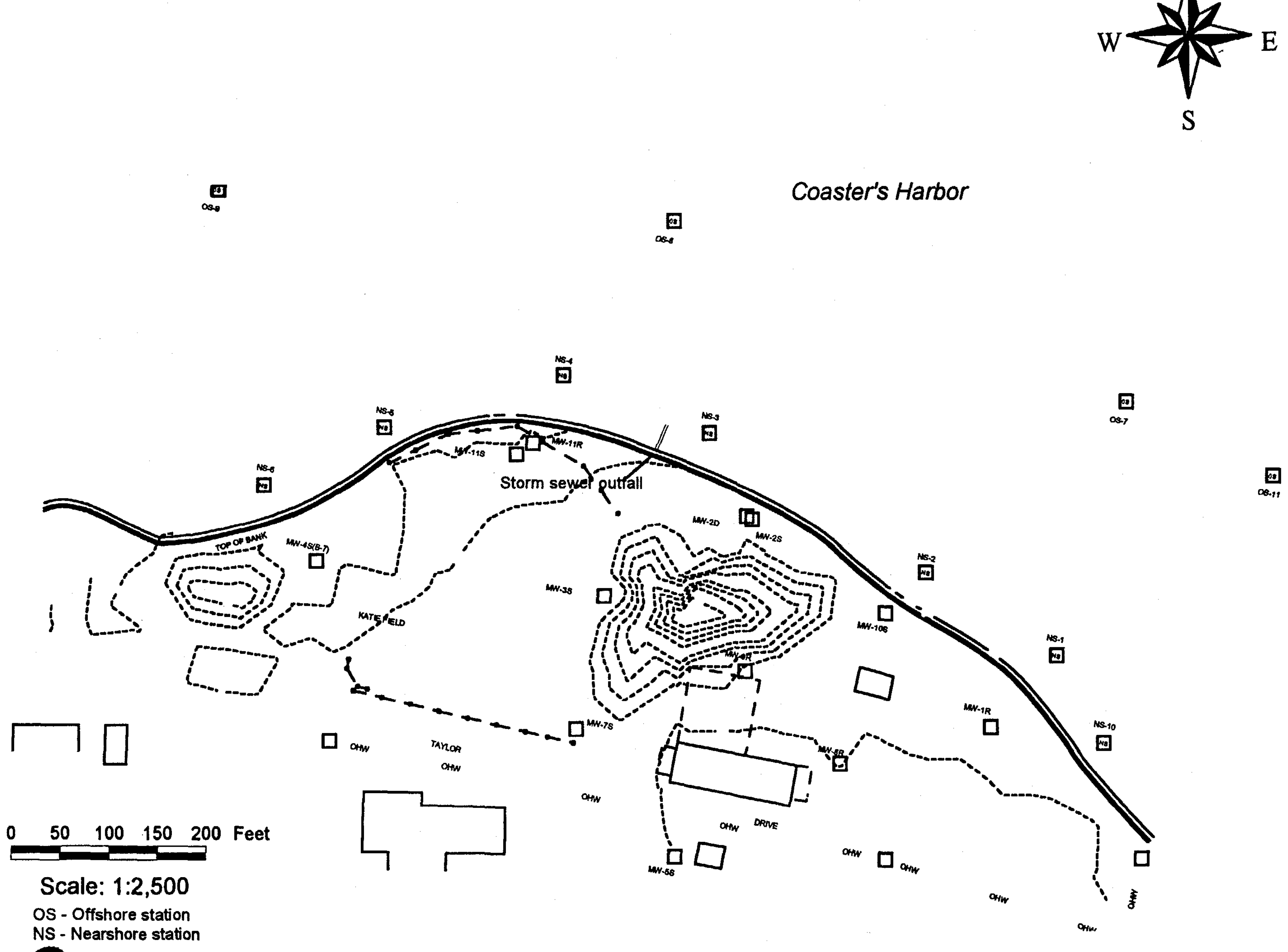


Figure C2-1. Marine stations sampled in 1993 by TRC at the Old Fire Fighting Training Area.



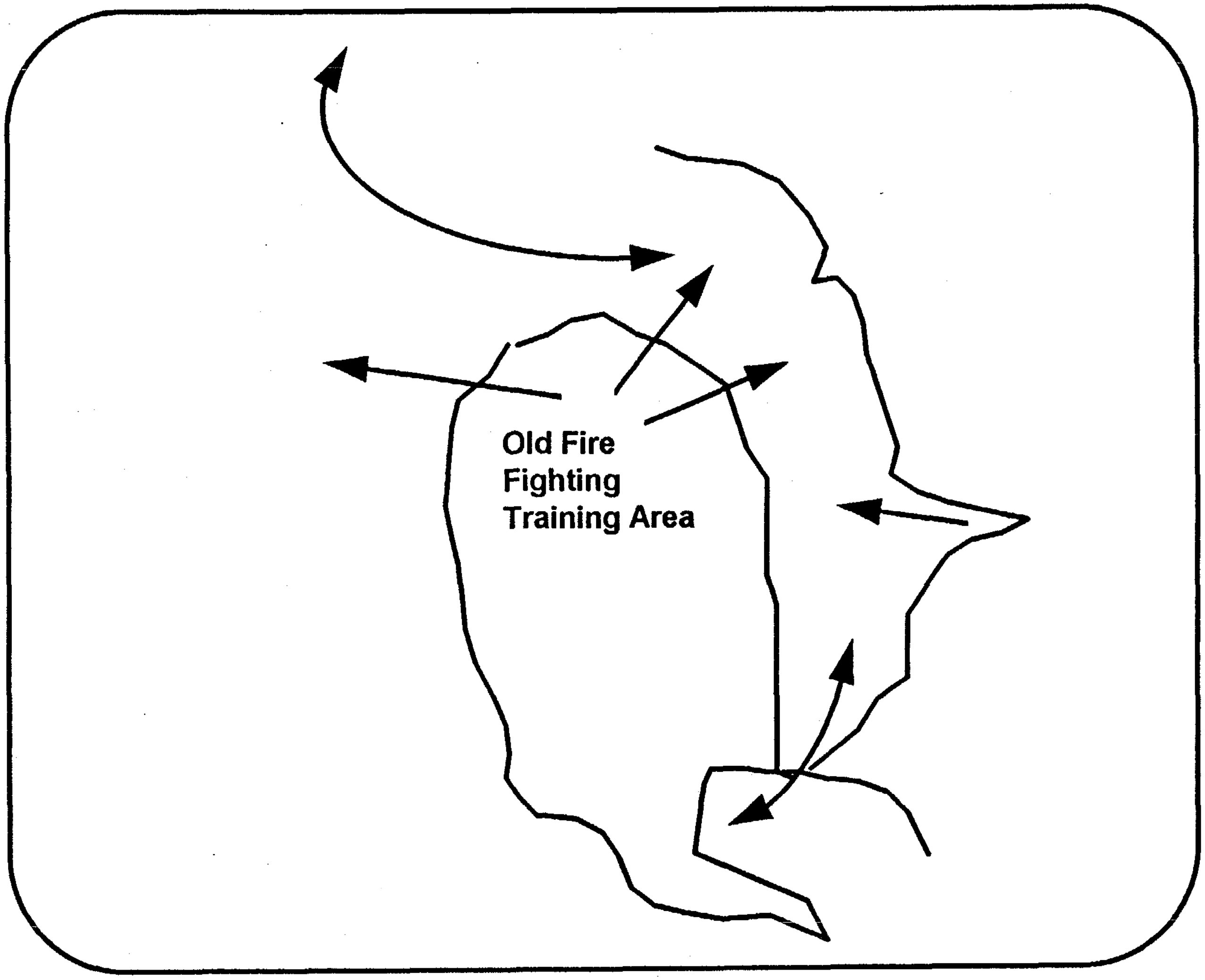



**Figure C2-2. Second tier conceptual model of contaminant transport for Old Fire Fighting Training Area**

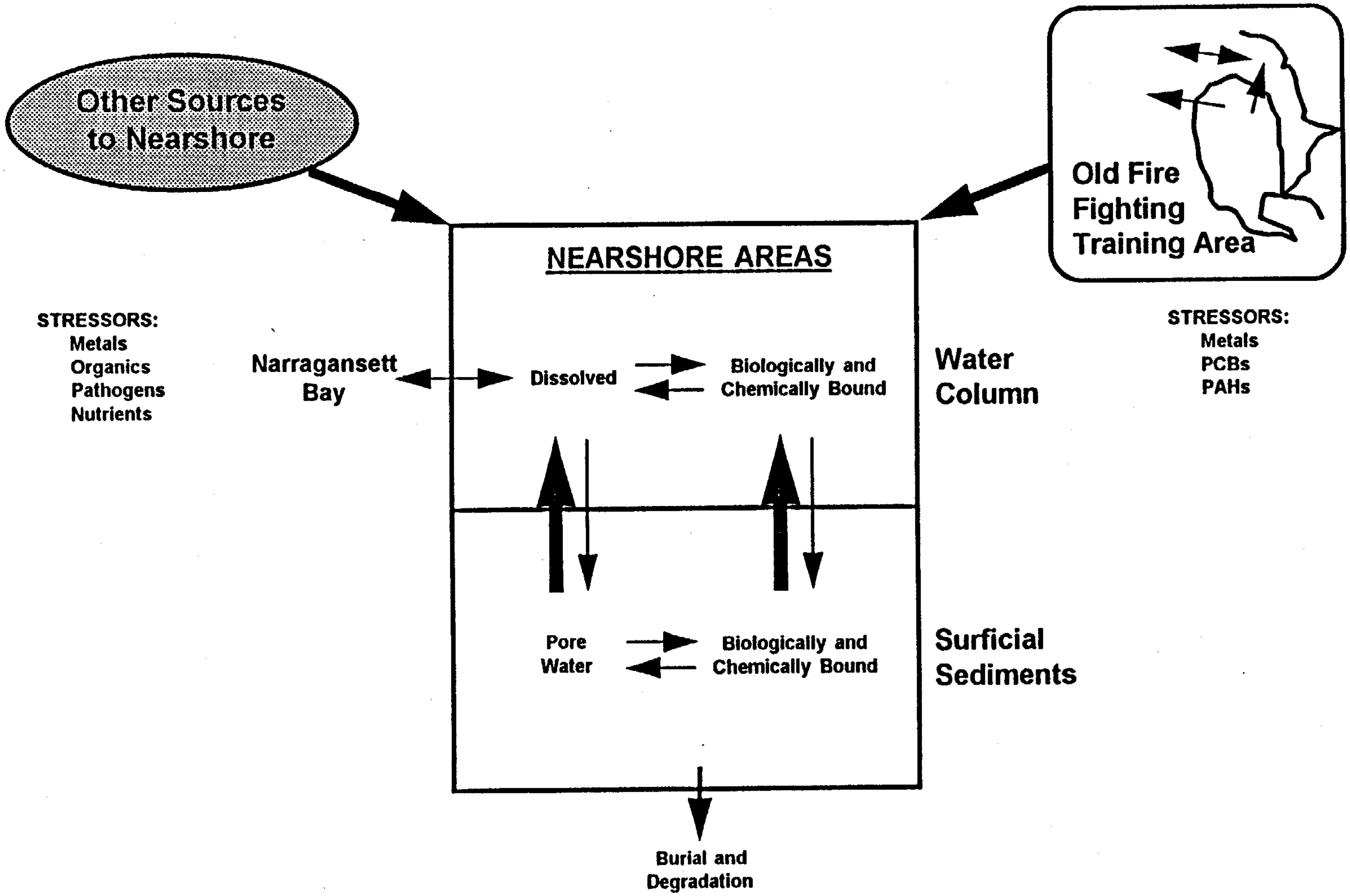



**Figure C2-3. Third tier conceptual model of contaminant behavior for Old Fire Fighting Training Area**

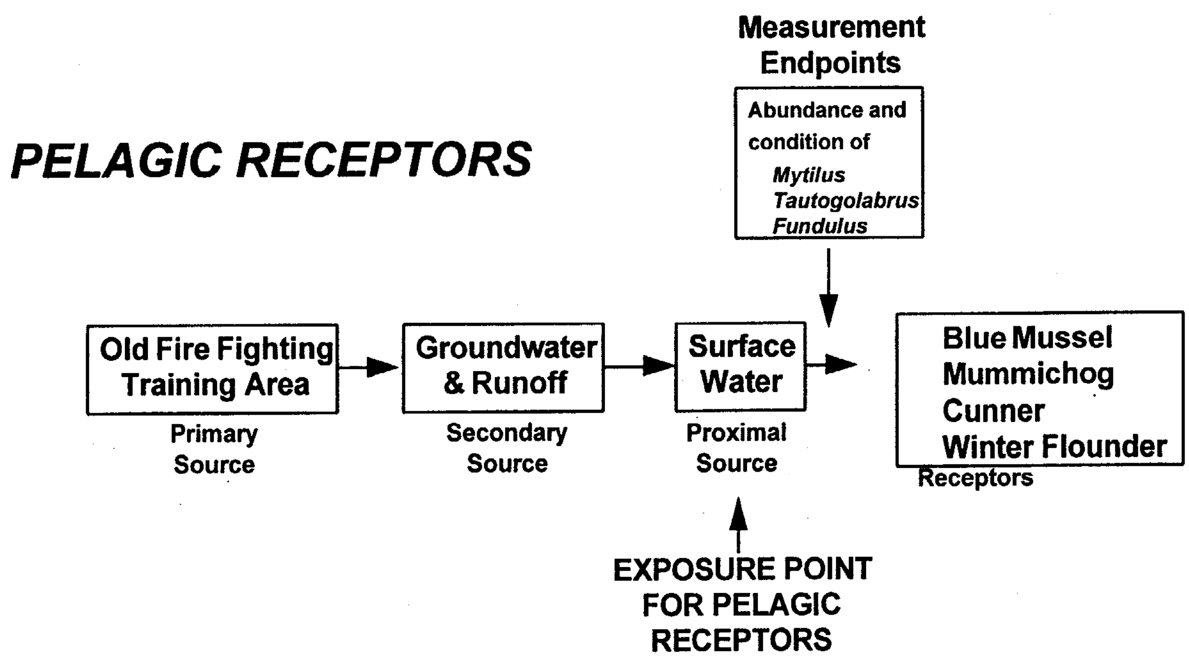



**Figure C2-4. Fourth tier conceptual model of contaminant transport for Old Fire Fighting Training Area: Exposure pathway to pelagic receptors.**

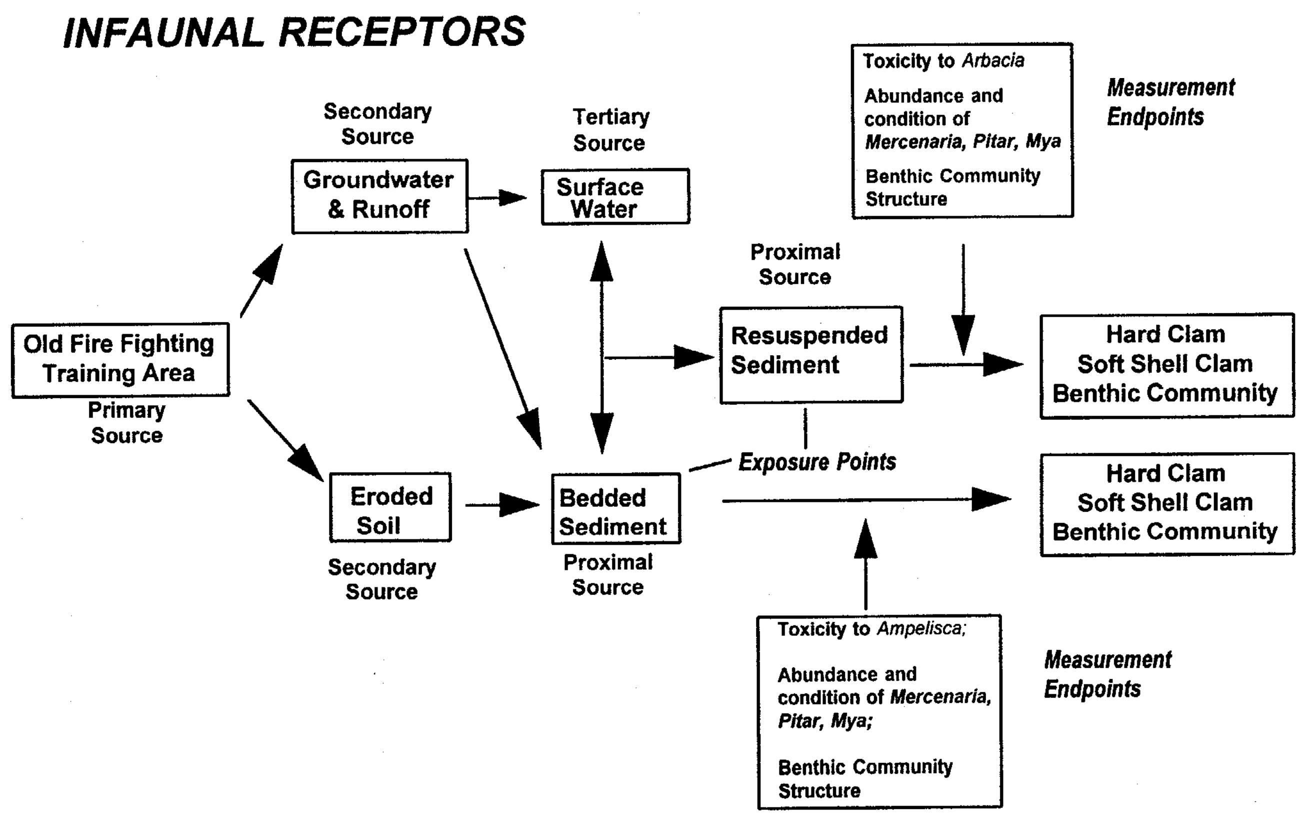



**Figure C2-5. Fourth tier conceptual model of contaminant transport for Old Fire Fighting Training Area: Exposure pathway to infaunal receptors.**

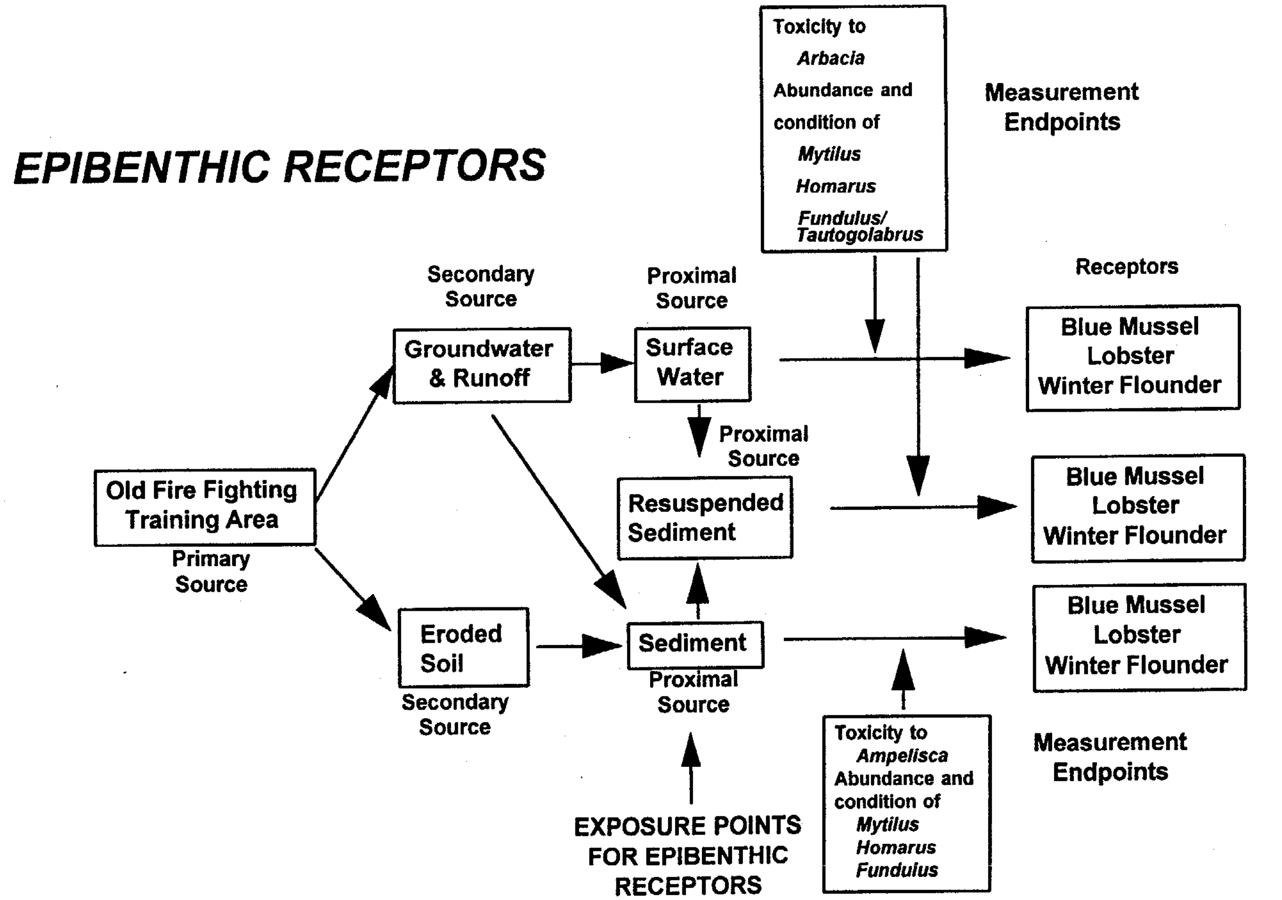



**Figure C2-6. Fourth tier conceptual model of contaminant transport for Old Fire Fighting Training Area: Exposure pathway to epibenthic receptors.**

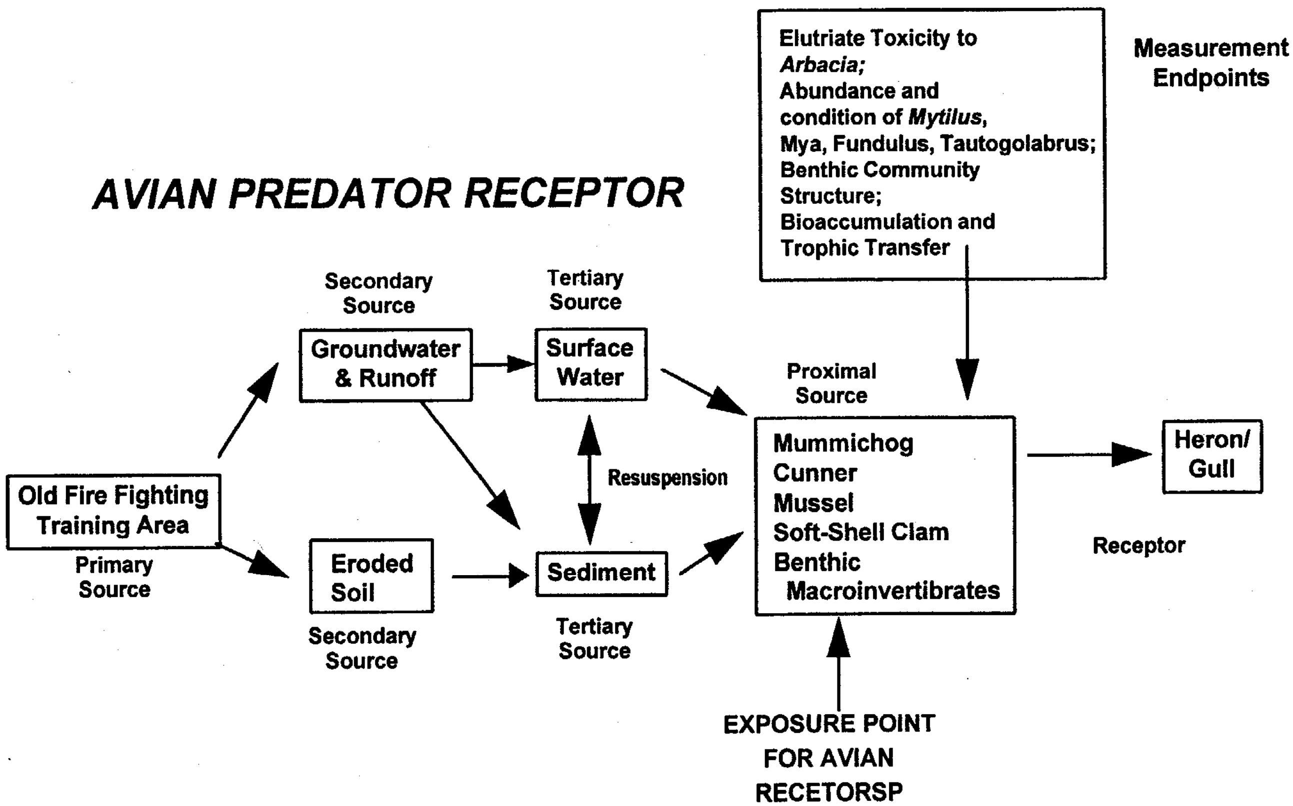



**Figure C2-7. Fourth tier conceptual model of contaminant transport for Old Fire Fighting Training Area: Exposure pathway to avian receptors.**

Figure C4-1.

Proposed Sampling Stations for the Old Fire Fighting Training Area Marine Ecological Risk Assessment

## Station Base Map

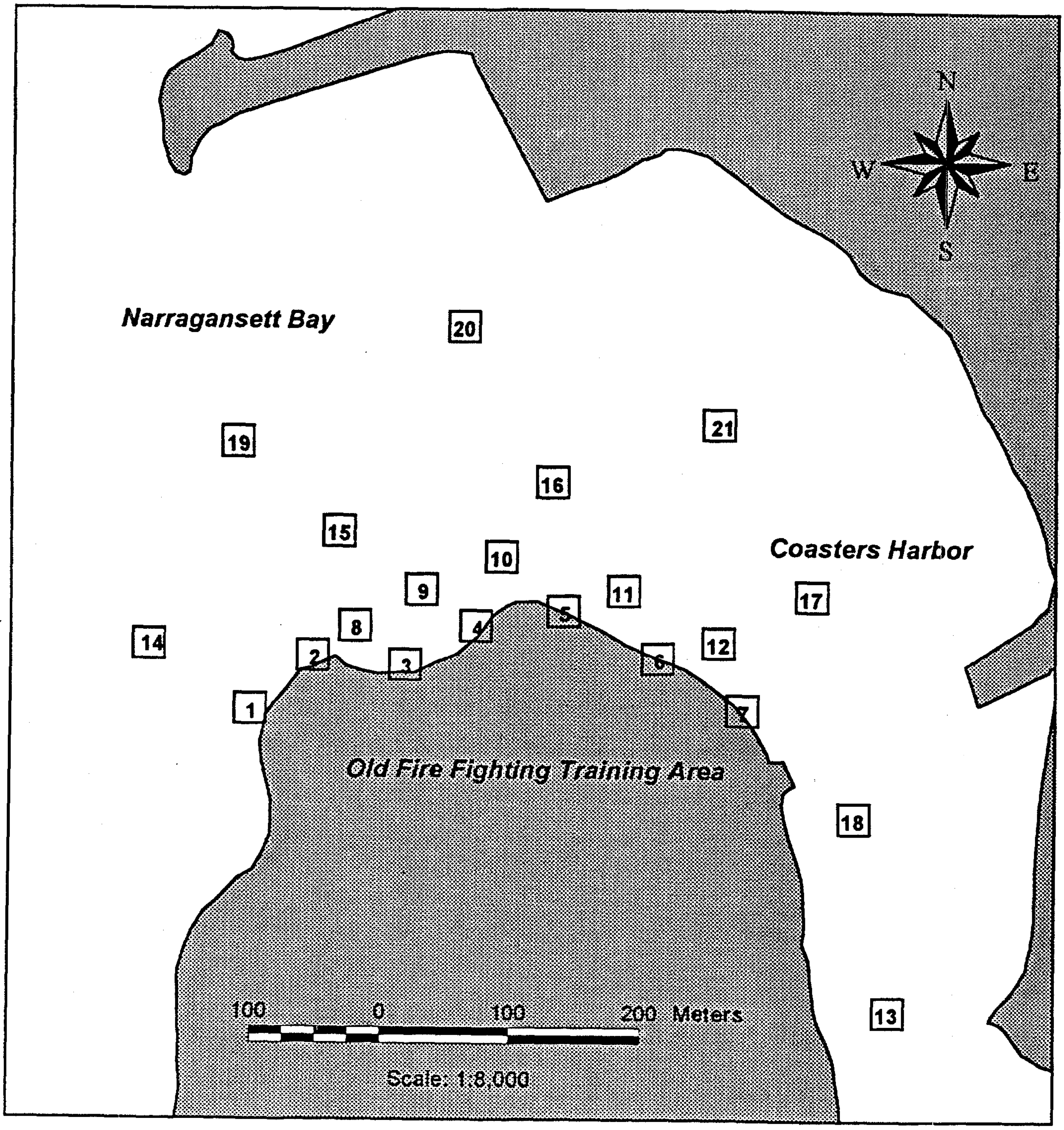


Figure C4-2.

Proposed Sampling Stations for the
Old Fire Fighting Training Area
Marine Ecological Risk Assessment

**Surface Sediment (0-15 cm) Collection Stations for Bulk and Elutriate Chemistry, Toxicity and Benthic Community Structure**

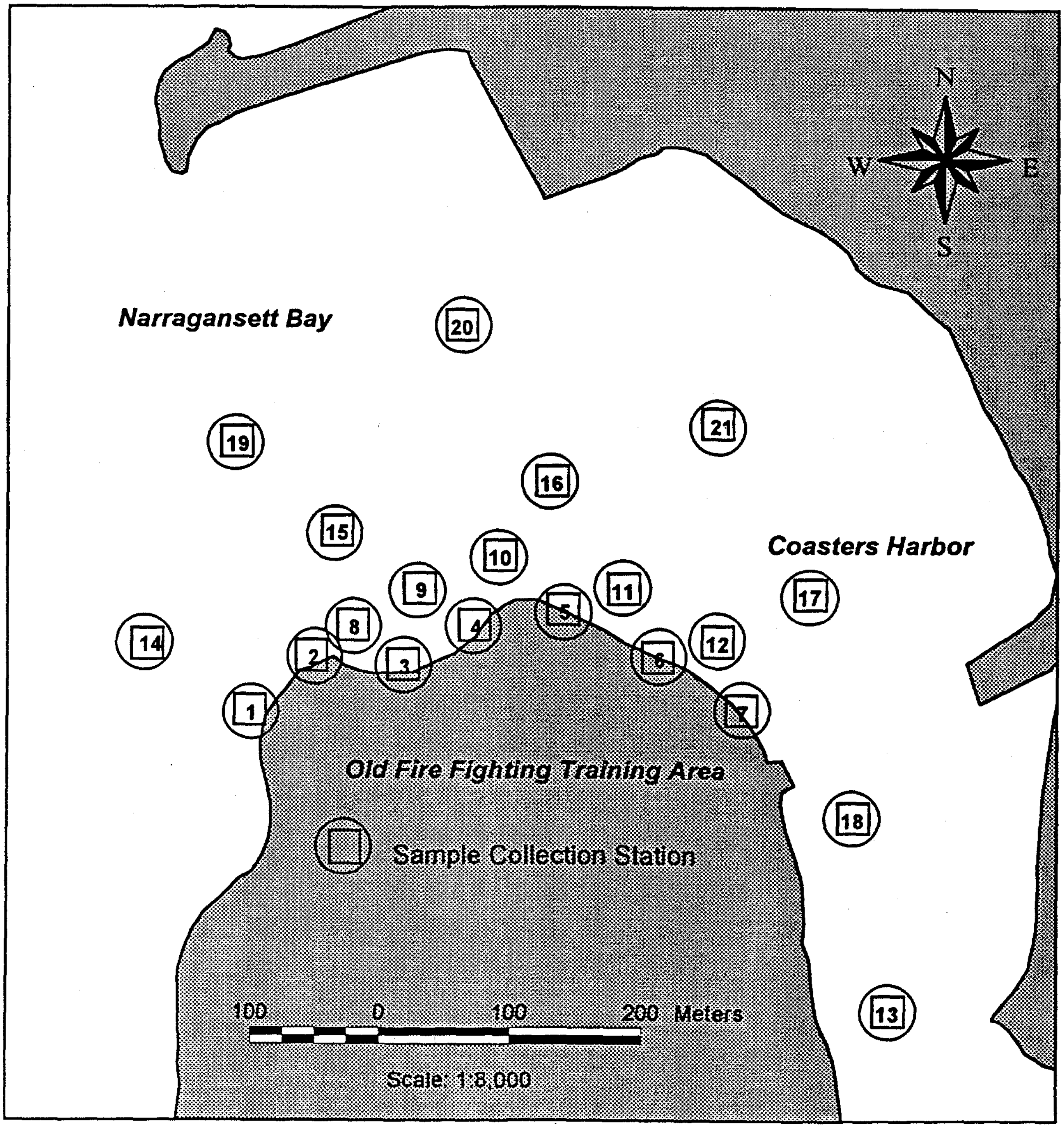


Figure C4-3.

## Proposed Sampling Stations for the Old Fire Fighting Training Area Marine Ecological Risk Assessment

### Sediment Coring Stations for Chemical Evaluation

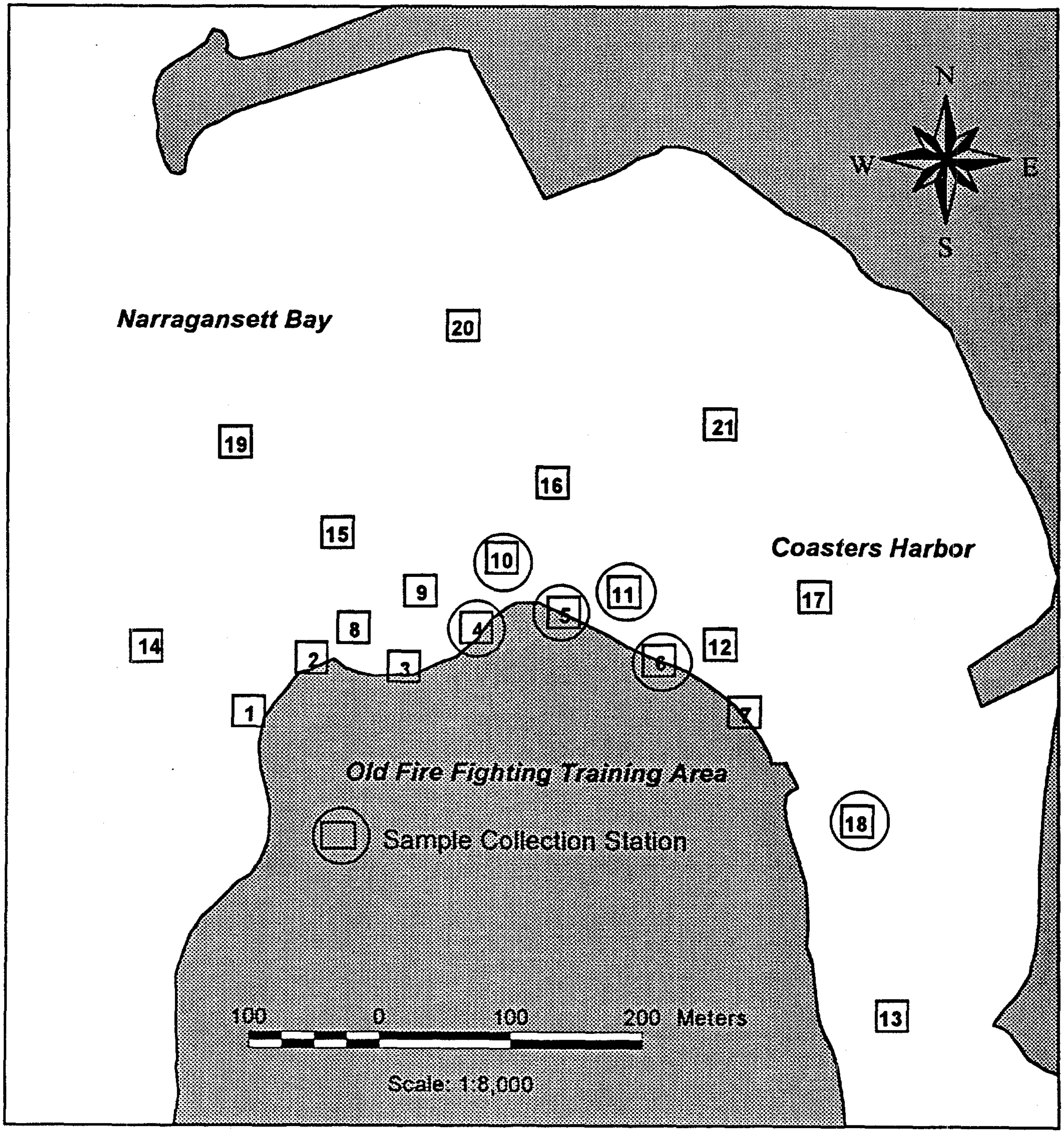


Figure C4-4.

# Proposed Sampling Stations for the Old Fire Fighting Training Area Marine Ecological Risk Assessment

## INDIGENOUS MUSSEL AND SOFT SHELL CLAM COLLECTION STATIONS

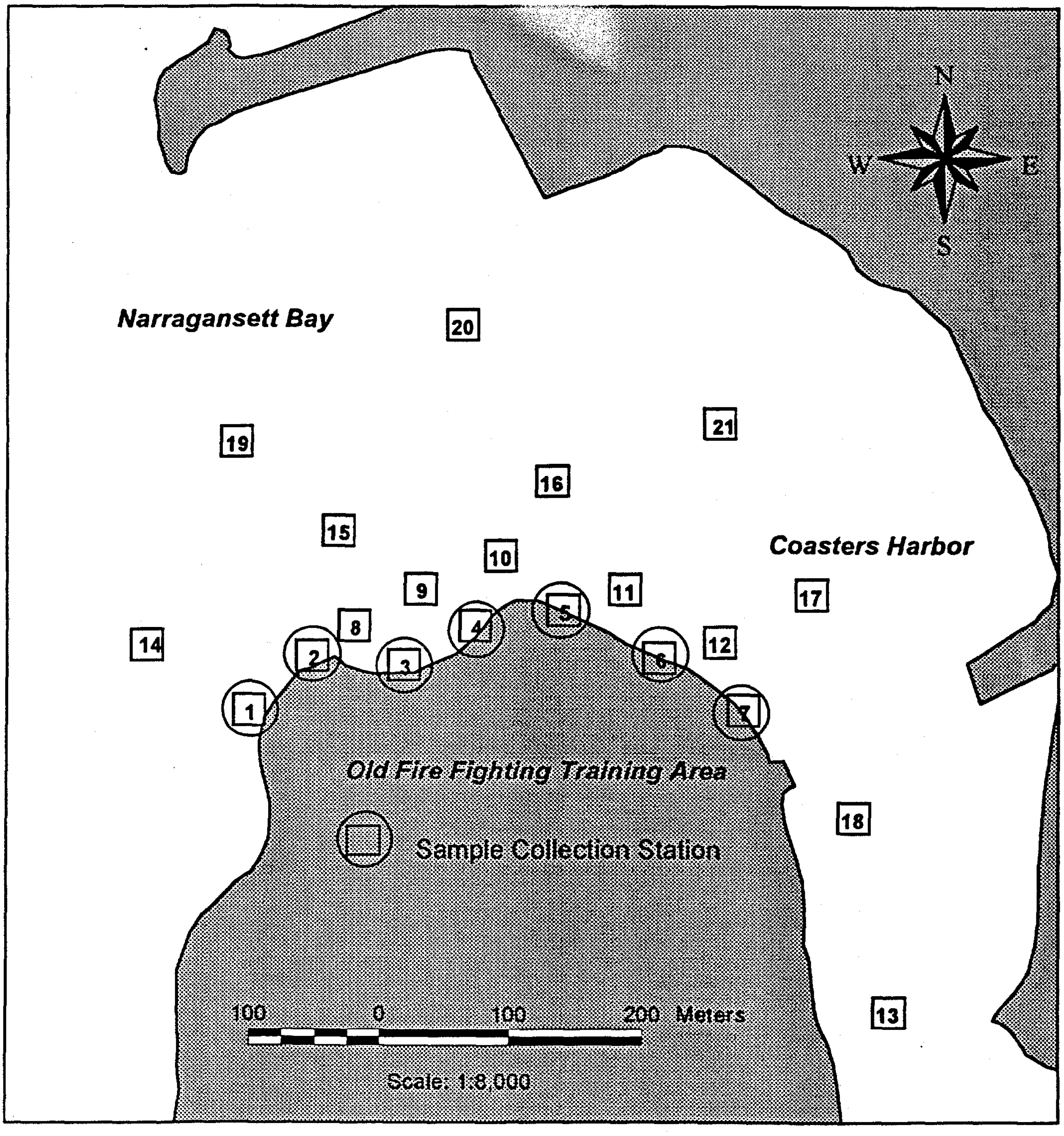


Figure C4-5.

## Proposed Sampling Stations for the Old Fire Fighting Training Area Marine Ecological Risk Assessment

### Hard Clam Collection Stations

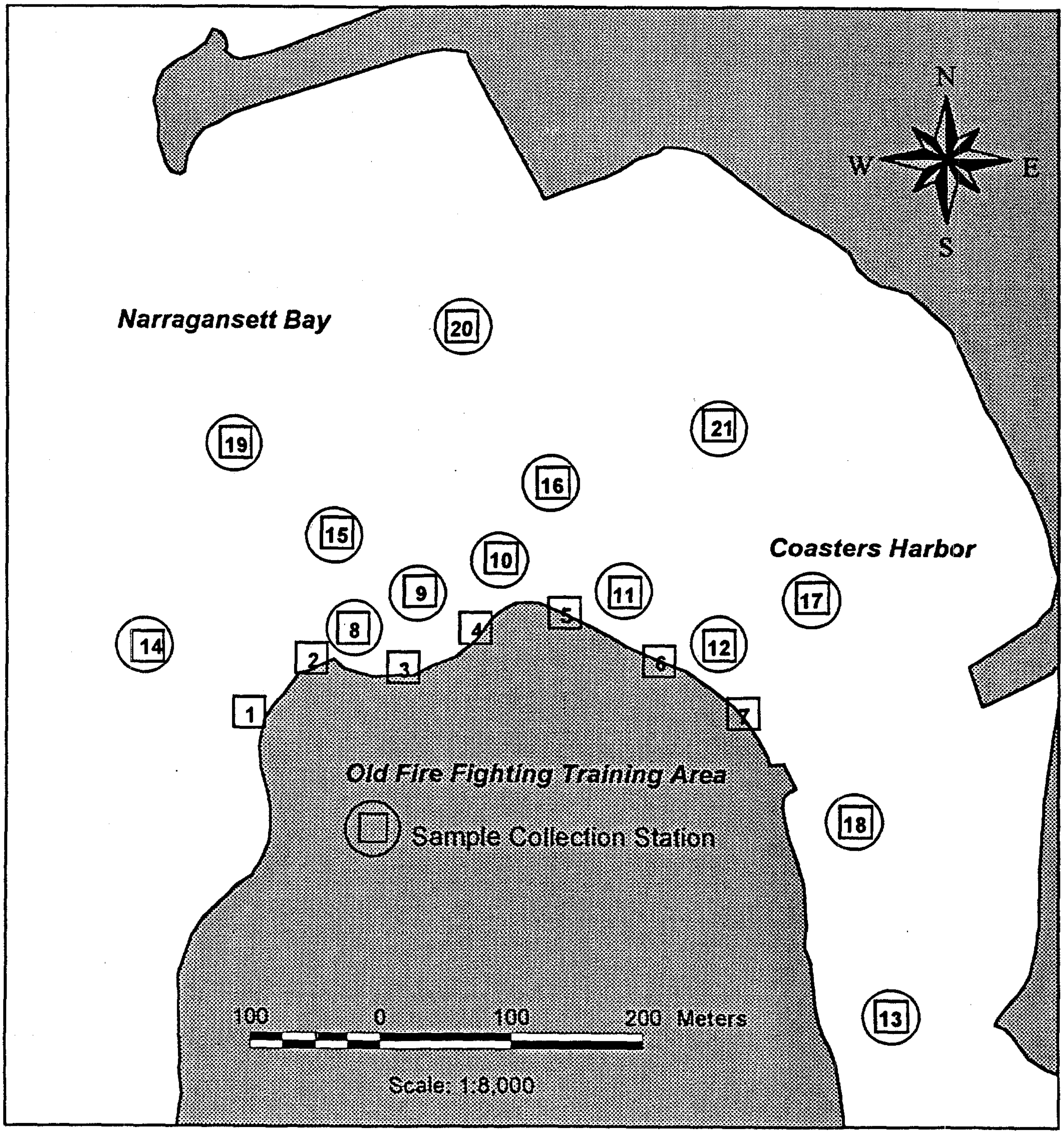


Figure C4-6.

# Proposed Sampling Stations for the Old Fire Fighting Training Area Marine Ecological Risk Assessment

## Deployed Mussels and Lobster Collections

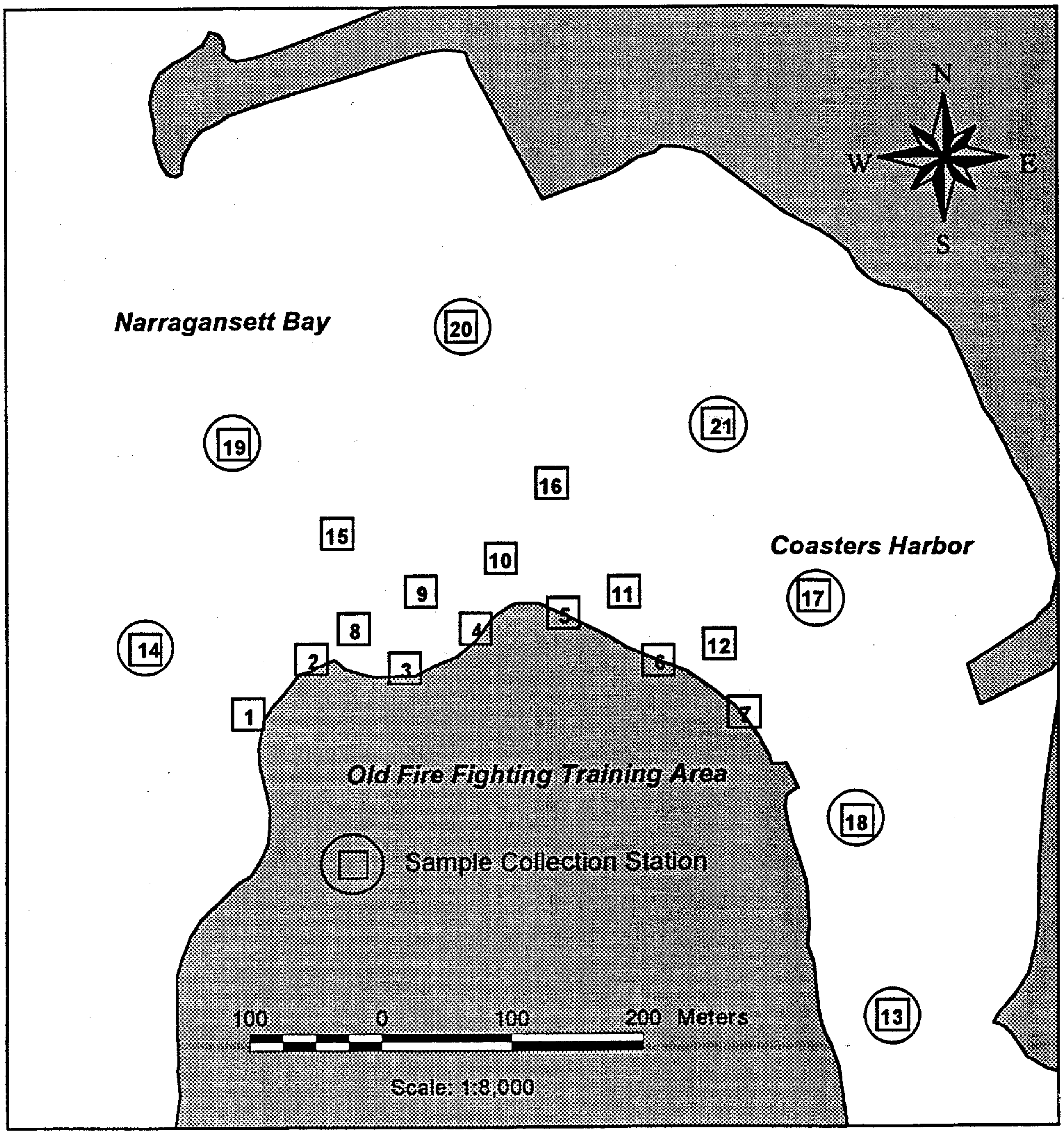


Figure C4-7. Old Fire Fighting Training Area Geophysical Survey Area

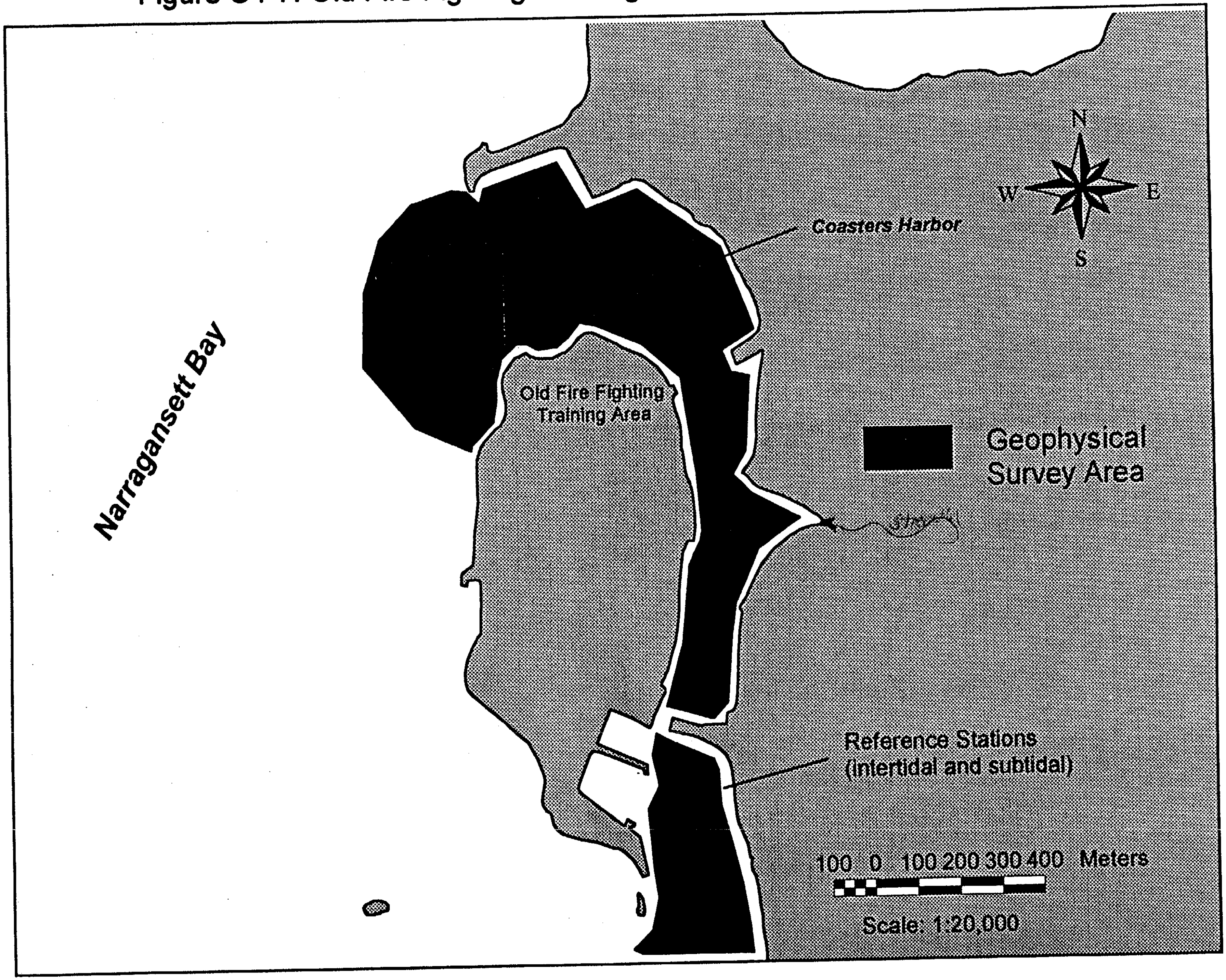


Figure C4-8. Old Fire Fighting Training Area Hydrographic Survey Lines

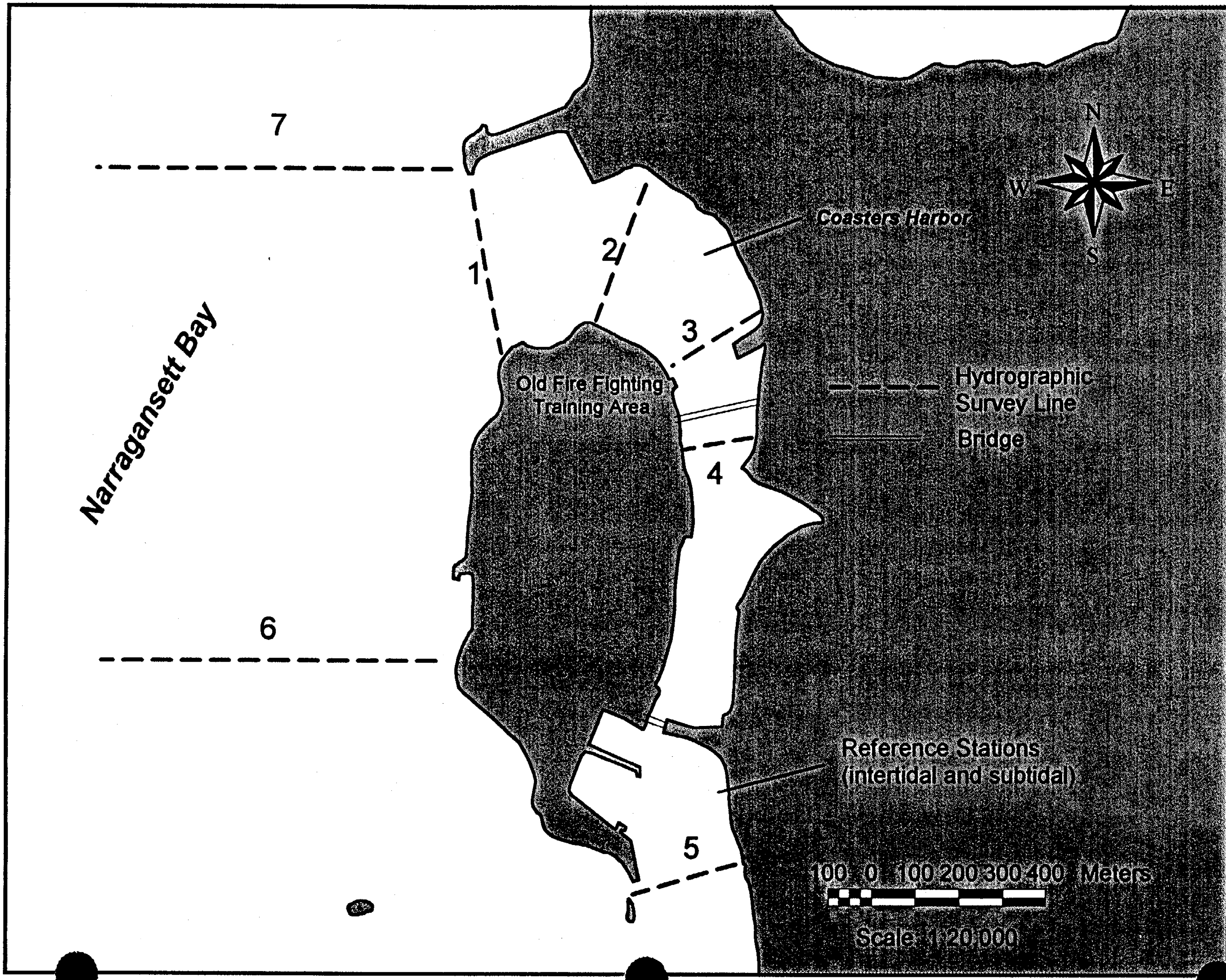


Table C2-1. Summary of detected chemical concentrations found in intertidal and subtidal sediments of Coasters Harbor adjacent to Old Fire Fighting Training Area (Site 09), Naval Education and Training Center, Newport RI. Data from TRC, 1994.

| | | FIELD ID | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Chemical Class | Target Analyte | S9NS1/2SMP | S9NS3/4SMP | S9NS5/6SMP | S9OS11SMP | S9OS7SMP | S9OS8SMP | S9OS9SMP |
| MET | Ag | 0.3 | 0.1 | 0.1 | 0.6 | 1.2 | 0.6 | 0.2 |
| | As | 7.2 | 4.0 | 5.1 | 11.0 | 11.4 | 9.3 | 2.5 |
| | Cd | 0.3 | 0.2 | 0.2 | 0.8 | 1.3 | 0.7 | 0.2 |
| | Cr | 32.5 | 23.8 | 24.3 | 53.2 | 70.6 | 42.6 | 40.1 |
| | Cu | 29.4 | 23.4 | 1.2 | 41.3 | 75.4 | 30.2 | 12.0 |
| | Hg | 0.1 | 0.1 | 0.1 | 0.2 | 0.4 | 0.2 | 0.1 |
| | Ni | 16.2 | 11.3 | 19.4 | 18.5 | 27.9 | 20.0 | 15.6 |
| | Pb | 81.6 | 38.6 | 33.4 | 62.1 | 123.0 | 57.8 | 24.8 |
| | Zn | 107.0 | 64.3 | 71.4 | 118.0 | 215.0 | 109.0 | 60.9 |
| PAH | C1-chrysenes | 1471.4 | 348.0 | 218.1 | 97.1 | 343.2 | 101.4 | 23.9 |
| | C1-dibenzothiophenes | 315.7 | 49.0 | 40.0 | 19.7 | 74.7 | 28.3 | 5.1 |
| | C1-fluoranthenes/pyrenes | 3480.2 | 761.2 | 505.5 | 216.9 | 840.9 | 283.4 | 62.9 |
| | C1-fluorenes | 419.4 | 75.1 | 43.6 | 20.3 | 68.6 | 27.6 | 5.9 |
| | C1-naphthalenes | 246.8 | 80.1 | 20.4 | 20.6 | 53.8 | 22.4 | 5.6 |
| | C1-phenanthrenes/anthracenes | 3361.4 | 731.1 | 458.6 | 120.4 | 540.3 | 180.2 | 39.2 |
| | C2-chrysenes | 899.6 | 230.5 | 155.8 | 93.3 | 283.7 | 106.0 | 19.1 |
| | C2-dibenzothiophenes | 468.9 | 74.9 | 74.5 | 31.0 | 98.0 | 40.2 | 7.6 |
| | C2-fluorenes | 655.6 | 152.0 | 89.9 | 41.2 | 105.8 | 42.6 | 7.7 |
| | C2-naphthalenes | 955.5 | 213.4 | 79.6 | 38.8 | 119.4 | 52.3 | 11.6 |
| | C2-phenanthrenes/anthracenes | 2256.9 | 517.2 | 346.0 | 109.5 | 420.0 | 156.7 | 32.7 |
| | C3-chrysenes | 404.9 | 134.6 | 91.0 | 78.3 | 206.4 | 85.5 | 13.2 |
| | C3-dibenzothiophenes | 269.8 | 52.7 | 47.1 | 39.7 | 99.3 | 44.9 | 8.6 |
| | C3-fluorenes | 852.2 | 256.2 | 146.4 | 73.5 | 193.5 | 75.0 | 14.9 |
| | C3-naphthalenes | 1727.1 | 368.4 | 177.6 | 56.6 | 188.5 | 79.7 | 14.4 |
| | C3-phenanthrenes/anthracenes | 900.7 | 243.0 | 154.6 | 63.9 | 266.6 | 90.4 | 19.7 |
| | C4-chrysenes | 129.4 | 50.5 | 29.2 | 52.1 | 96.6 | 40.2 | 5.8 |
| | C4-naphthalenes | 1275.9 | 255.3 | 132.7 | 47.3 | 146.6 | 70.9 | 14.2 |
| | C4-phenanthrenes/anthracenes | 1245.3 | 357.8 | 198.5 | 109.6 | 297.9 | 93.1 | 18.0 |
| PAH | acenaphthene | 370.8 | 85.0 | 23.9 | 13.4 | 72.5 | 18.8 | 3.6 |
| | acenaphthylene | 419.5 | 230.6 | 107.4 | 22.8 | 96.3 | 27.6 | 10.2 |
| | anthracene | 1003.4 | 291.7 | 138.5 | 40.6 | 204.3 | 60.6 | 15.2 |
| | benz[a]anthracene | 2717.7 | 757.6 | 436.8 | 139.7 | 630.9 | 158.6 | 37.2 |
| | benzo[a]pyrene | 2683.1 | 761.5 | 391.4 | 171.9 | 649.8 | 181.7 | 36.5 |
| | benzo[b]fluoranthene | 3173.0 | 930.9 | 543.1 | 259.4 | 929.7 | 270.7 | 62.8 |
| | benzo[e]pyrene | 1636.5 | 462.9 | 270.4 | 142.3 | 475.7 | 147.3 | 32.7 |
| | benzo[g,h,i]perylene | 1326.6 | 416.0 | 198.5 | 135.4 | 348.5 | 113.2 | 20.8 |
| | benzo[k]fluoranthene | 1249.9 | 394.5 | 222.3 | 100.3 | 347.9 | 100.2 | 21.5 |
| | biphenyl* | 44.4 | 12.0 | 3.8 | 6.3 | 15.1 | 6.7 | 1.6 |
| | chrysene | 2835.5 | 790.7 | 490.6 | 129.4 | 523.8 | 149.4 | 34.4 |
| | dibenz[a,h]anthracene | 313.9 | 89.8 | 48.3 | 31.5 | 104.3 | 29.9 | 5.9 |
| | dibenzofuran* | 219.2 | 65.2 | 20.8 | 10.8 | 36.5 | 10.7 | 3.4 |
| | dibenzothiophene | 283.7 | 69.0 | 33.6 | 12.4 | 49.6 | 14.8 | 3.8 |
| | fluoranthene | 5600.4 | 1985.1 | 1355.9 | 353.5 | 1499.1 | 413.5 | 115.3 |
| | fluorene | 504.6 | 113.7 | 45.0 | 17.6 | 82.7 | 23.7 | 7.5 |
| | indeno[1,2,3-c,d]pyrene | 1538.0 | 490.6 | 236.2 | 141.0 | 401.8 | 122.4 | 25.3 |
| | naphthalene | 143.5 | 84.8 | 25.0 | 23.2 | 46.8 | 20.3 | 5.2 |
| | perylene | 674.9 | 210.4 | 116.5 | 64.2 | 153.5 | 51.8 | 11.2 |
| | phenanthrene | 4252.2 | 1223.9 | 614.7 | 156.2 | 817.3 | 224.4 | 66.4 |
| | pyrene | 5510.7 | 1700.9 | 1123.8 | 327.2 | 1409.9 | 438.8 | 104.8 |
| | Sum PAHs[2] | 36282.2 | 11101.5 | 6425.8 | 2288.2 | 8859.1 | 2574.5 | 621.6 |
| PCB | CL10(209) | | | | | | 1.8 | |
| | CL2(08) | | | | | | | |
| | CL3(18) | 0.8 | | | | | | |
| | CL3(28) | 1.3 | 0.4 | 0.3 | | | | |
| | CL4(44) | | | | | | | |
| | CL4(52) | 1.7 | | | 0.3 | 0.6 | 0.4 | |
| | CL4(66) | 0.9 | | 0.6 | | 1.1 | | |
| | CL4(77) | | | | | | | |
| | CL5(101) | 1.9 | 1.8 | 0.7 | | 2.9 | 1.6 | |
| | CL5(105) | | | | | | | |
| | CL5(118) | 1.2 | | 0.6 | 1.1 | 2.6 | 1.4 | 0.5 |
| | CL5(126) | | | | | | | |
| | CL6(128) | 4.4 | 2.3 | 1.1 | 0.6 | 1.5 | 0.6 | |
| | CL6(138) | 1.7 | 0.7 | 0.7 | 1.6 | 4.0 | 2.0 | 0.7 |
| | CL6(153) | 3.1 | 1.4 | 1.3 | 2.2 | 5.2 | 2.6 | 0.9 |
| | CL7(170) | 5.6 | 2.3 | 1.3 | 1.6 | 4.8 | 1.3 | |
| | CL7(180) | 1.8 | 1.3 | 0.6 | 1.0 | 2.6 | 1.1 | |
| | CL7(187) | 3.1 | 1.6 | 0.9 | | 2.3 | 1.1 | |
| | CL8(195) | | | | | | | |
| | CL9(206) | | | | | | | |
| | PCB Sum of Congeners x 2 | 62.5 | 30.9 | 24.6 | 32.3 | 65.5 | 36.8 | 16.7 |

[1]Concentration units: Metals (MET) - ug/g; PAHs, PCBs - ng/g.
NS = Nearshore, OS = Offshore, SMP = Sample
*SVOC
[2]Sum of PAH analytes; including biphenyl, but excluding dibenzofuran

TABLE C2-2. Data Summary and Identification of Contaminants of Concern (CoC) for the OFFTA Sediment Contaminants (Data from TRC, 1994).

## SEDIMENT

| CLASS[1] | ANALYTE | FREQUENCY OF DETECTION # Detects | # Samples | % | RANGE OF CONCENTRATION[a] Minimum | Maximum | MEAN CONCENTRATION[b] | 95% UPPER CONFIDENCE LIMIT | BACKGROUND MEAN CONCENTRATION[b] | MINIMUM BENCHMARK VALUE[c] | 95% UCL or MAX CONCENTRATION[d] Exceeds Minimum Benchmark? | Exceeds Background? | FREQUENCY OF DETECTION > 5%? | IS TARGET ANALYTE A CoC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MET | Ag | 7 | 7 | 100% | 0.12 | 1.16 | 0.4 | 1.0 | 0.1 | 1 | YES | YES | YES | YES |
| | As | 7 | 7 | 100% | 2.5 | 11.4 | 7.2 | 12.9 | 4.5 | 8.2 | + YES | YES | YES | YES |
| | Cd | 7 | 7 | 100% | 0.2 | 1.3 | 0.5 | 1.2 | 0.1 | 1.2 | YES | YES | YES | YES |
| | Cr | 7 | 7 | 100% | 23.8 | 70.6 | 41.0 | 68.4 | 43.6 | 81 | NO | YES | YES | YES |
| | Cu | 7 | 7 | 100% | 1.2 | 75.4 | 30.4 | 69.4 | 17.1 | 34 | YES | YES | YES | YES |
| | Hg | 7 | 7 | 100% | 0.1 | 0.4 | 0.2 | 0.4 | 0.4 | NA | NA | YES | YES | YES |
| | Ni | 7 | 7 | 100% | 11.3 | 27.9 | 18.4 | 26.8 | 18.7 | 20.9 | YES | YES | YES | YES |
| | Pb | 7 | 7 | 100% | 24.8 | 123.0 | 60.2 | 115.6 | 32.9 | 46.7 | YES | YES | YES | YES |
| | Zn | 7 | 7 | 100% | 60.9 | 215.0 | 106.5 | 193.8 | 78.4 | 150 | YES | YES | YES | YES |
| PAH | C1-chrysenes | 7 | 7 | 100% | 23.9 | 1471.4 | 371.9 | 1192.9 | 33.2 | NA | NA | YES | YES | YES |
| | C1-dibenzothiophenes | 7 | 7 | 100% | 5.1 | 315.7 | 76.1 | 253.2 | 5.2 | NA | NA | YES | YES | YES |
| | C1-fluoranthenes/pyrenes | 7 | 7 | 100% | 62.9 | 3480.2 | 878.7 | 2816.9 | 68.4 | NA | NA | YES | YES | YES |
| | C1-fluorenes | 7 | 7 | 100% | 5.9 | 419.4 | 94.4 | 333.0 | 5.9 | NA | NA | YES | YES | YES |
| | C1-naphthalenes | 7 | 7 | 100% | 5.6 | 246.8 | 64.2 | 202.6 | 6.8 | NA | NA | YES | YES | YES |
| | C1-phenanthrenes/anthracenes | 7 | 7 | 100% | 39.2 | 3361.4 | 775.9 | 2689.6 | 37.6 | NA | NA | YES | YES | YES |
| | C2-chrysenes | 7 | 7 | 100% | 19.1 | 899.6 | 255.4 | 743.2 | 32.8 | NA | NA | YES | YES | YES |
| | C2-dibenzothiophenes | 7 | 7 | 100% | 7.6 | 468.9 | 113.6 | 375.4 | 8.5 | NA | NA | YES | YES | YES |
| | C2-fluorenes | 7 | 7 | 100% | 7.7 | 655.6 | 156.4 | 525.9 | 10.2 | NA | NA | YES | YES | YES |
| | C2-naphthalenes | 7 | 7 | 100% | 11.6 | 955.5 | 210.1 | 760.0 | 13.1 | NA | NA | YES | YES | YES |
| | C2-phenanthrenes/anthracenes | 7 | 7 | 100% | 32.7 | 2256.9 | 548.4 | 1816.9 | 35.9 | NA | NA | YES | YES | YES |
| | C3-chrysenes | 7 | 7 | 100% | 13.2 | 404.9 | 144.9 | 356.3 | 23.1 | NA | NA | YES | YES | YES |
| | C3-dibenzothiophenes | 7 | 7 | 100% | 8.6 | 269.8 | 80.3 | 224.2 | 10.5 | NA | NA | YES | YES | YES |
| | C3-fluorenes | 7 | 7 | 100% | 14.9 | 852.2 | 230.2 | 699.4 | 18.1 | NA | NA | YES | YES | YES |
| | C3-naphthalenes | 7 | 7 | 100% | 14.4 | 1727.1 | 373.2 | 1370.8 | 16.2 | NA | NA | YES | YES | YES |
| | C3-phenanthrenes/anthracenes | 7 | 7 | 100% | 19.7 | 900.7 | 248.4 | 743.1 | 24.0 | NA | NA | YES | YES | YES |
| | C4-chrysenes | 7 | 7 | 100% | 5.8 | 129.4 | 57.7 | 126.5 | 10.8 | NA | NA | YES | YES | YES |
| | C4-naphthalenes | 7 | 7 | 100% | 14.2 | 1275.9 | 277.5 | 1011.1 | 11.1 | NA | NA | YES | YES | YES |
| | C4-phenanthrenes/anthracenes | 7 | 7 | 100% | 18.0 | 1245.3 | 331.5 | 1020.4 | 33.7 | NA | NA | YES | YES | YES |

Notes
[1]Concentration units: Metals (MET) - ug/g; PAHs, PCBs - ng/g.
[a]The range of concentrations reported for site data excludes non-detected values.
[b]1/2 Sample Quantitation Limits substituted for non-detects when calculating mean of site and reference station data.
[c]Minimum benchmark = NOAA ER-L (Long et. al.,1995)
[d]If 95% UCL is greater than the Maximum Concentration, as indicated with a "+", then Maximum Concentration is used to screen against benchmark or background.
[e]Sum of PAH analytes; including biphenyl, but excluding dibenzofuran
NA = Benchmark Not Available
*SVOC

TABLE C2-2. (Continued)

## SEDIMENT

| | | FREQUENCY OF DETECTION | | | RANGE OF CONCENTRATION[a] | | MEAN CONCENTRATION[b] | 95% UPPER CONFIDENCE LIMIT | BACKGROUND MEAN CONCENTRATION[b] | MINIMUM BENCHMARK VALUE[c] | 95% UCL or MAX CONCENTRATION[d] | | FREQUENCY OF DETECTION > 5%? | IS TARGET ANALYTE A CoC? |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| CLASS[1] | ANALYTE | # Detects | # Samples | % | Minimum | Maximum | | | | | Exceeds Minimum Benchmark? | Exceeds Background? | | |
| PAH | acenaphthene | 7 | 7 | 100% | 3.59 | 370.77 | | | 3.1 | 16 | NO | NO | NO | NO |
| | acenaphthylene | 7 | 7 | 100% | 10.2 | 419.5 | 130.6 | 379.3 | 8.8 | 44 | NO | YES | YES | YES |
| | anthracene | 7 | 7 | 100% | 15.2 | 1003.4 | 250.6 | 843.7 | 15.5 | 85.3 | NO | YES | YES | YES |
| | benz[a]anthracene | 7 | 7 | 100% | 37.2 | 2717.7 | 696.9 | 2284.8 | 40.8 | 261 | NO | YES | YES | YES |
| | benzo[a]pyrene | 7 | 7 | 100% | 36.5 | 2683.1 | 696.6 | 2254.8 | 47.8 | 430 | NO | YES | YES | YES |
| | benzo[b]fluoranthene | 7 | 7 | 100% | 62.8 | 3173.0 | 881.4 | 2680.7 | 71.3 | 3200 | NO | YES | YES | YES |
| | benzo[e]pyrene | 7 | 7 | 100% | 32.7 | 1636.5 | 452.5 | 1379.0 | 40.0 | NA | NA | YES | YES | YES |
| | benzo[g,h,i]perylene | 7 | 7 | 100% | 20.8 | 1326.6 | 365.6 | 1117.5 | 32.7 | NA | NA | YES | YES | YES |
| | benzo[k]fluoranthene | 7 | 7 | 100% | 21.5 | 1249.9 | 348.1 | 1057.8 | 26.8 | NA | NA | YES | YES | YES |
| | biphenyl* | 7 | 7 | 100% | 1.6 | 44.4 | 12.8 | 37.6 | 2.2 | NA | NA | YES | YES | YES |
| | chrysene | 7 | 7 | 100% | 34.4 | 2836.5 | 707.7 | 2377.9 | 36.1 | 384 | NO | YES | YES | YES |
| | dibenz[a,h]anthracene | 7 | 7 | 100% | 5.9 | 313.9 | 89.1 | 265.9 | 7.8 | 63.4 | NO | YES | YES | YES |
| | dibenzofuran* | 7 | 7 | 100% | 3.4 | 219.2 | 52.4 | 184.2 | 3.4 | NA | NA | YES | YES | YES |
| | dibenzothiophene | 7 | 7 | 100% | 3.8 | 283.7 | 66.7 | 236.3 | 3.4 | NA | NA | YES | YES | YES |
| | fluoranthene | 7 | 7 | 100% | 115.3 | 5600.4 | 1617.5 | 4793.6 | 97.7 | 600 | NO | YES | YES | YES |
| | fluorene | 7 | 7 | 100% | 7.5 | 504.6 | 113.5 | 419.4 | 6.2 | 19 | NO | YES | YES | YES |
| | indeno[1,2,3-c,d]pyrene | 7 | 7 | 100% | 25.3 | 1538.0 | 422.2 | 1298.5 | 36.0 | NA | NA | YES | YES | YES |
| | naphthalene | 7 | 7 | 100% | 5.2 | 143.5 | 49.8 | 129.7 | 8.1 | 160 | NO | YES | YES | YES |
| | perylene | 7 | 7 | 100% | 11.2 | 674.9 | 183.2 | 567.4 | 16.3 | NA | NA | YES | YES | YES |
| | phenanthrene | 7 | 7 | 100% | 66.4 | 4252.2 | 1050.7 | 3574.9 | 49.7 | 240 | NO | YES | YES | YES |
| | pyrene | 7 | 7 | 100% | 104.8 | 5510.7 | 1516.6 | 4662.3 | 94.4 | 665 | NO | YES | YES | YES |
| | Sum PAHs | 7 | 7 | 100% | 625.1 | 36501.4 | 9788.5 | 30809.0 | 648.2 | 4022 | NO | YES | YES | YES |
| PCB | CL10(209) | 1 | 7 | 14% | 1.8 | 1.8 | 1.8 | | 0.7 | NA | + NA | YES | YES | YES |
| | CL2(08) | 0 | 7 | 0% | | | | | 1.0 | NA | NA | YES | NO | NO |
| | CL3(18) | 1 | 7 | 14% | 0.8 | 0.8 | 0.8 | | 0.6 | NA | + NA | YES | YES | YES |
| | CL3(28) | 3 | 7 | 43% | 0.3 | 1.3 | 0.7 | 1.6 | 0.4 | NA | + NA | YES | YES | YES |
| | CL4(44) | 0 | 7 | 0% | | | | | 0.4 | NA | NA | YES | NO | NO |
| | CL4(52) | 4 | 7 | 57% | 0.3 | 1.7 | 0.7 | 1.8 | 0.5 | NA | + NA | YES | YES | YES |
| | CL4(66) | 3 | 7 | 43% | 0.6 | 1.1 | 0.8 | 1.3 | 0.3 | NA | + NA | YES | YES | YES |
| | CL4(77) | 0 | 7 | 0% | | | | | 0.6 | NA | NA | YES | NO | NO |
| | CL5(101) | 5 | 7 | 71% | 0.7 | 2.9 | 1.8 | 3.1 | 0.5 | NA | + NA | YES | YES | YES |
| | CL5(105) | 0 | 7 | 0% | | | | | 0.2 | NA | NA | YES | NO | NO |
| | CL5(118) | 6 | 7 | 86% | 0.5 | 2.6 | 1.2 | 2.4 | 0.5 | NA | NA | YES | YES | YES |
| | CL5(126) | 0 | 7 | 0% | | | | | 0.5 | NA | NA | YES | NO | NO |
| | CL6(128) | 6 | 7 | 86% | 0.6 | 4.4 | 1.8 | 4.1 | 0.3 | NA | NA | YES | YES | YES |
| | CL6(138) | 7 | 7 | 100% | 0.7 | 4.0 | 1.6 | 3.6 | 1.3 | NA | NA | YES | YES | YES |
| | CL6(153) | 7 | 7 | 100% | 0.9 | 5.2 | 2.4 | 4.7 | 1.8 | NA | NA | YES | YES | YES |
| | CL7(170) | 6 | 7 | 86% | 1.3 | 5.6 | 2.8 | 5.9 | 0.9 | NA | + NA | YES | YES | YES |
| | CL7(180) | 6 | 7 | 86% | 0.6 | 2.6 | 1.4 | 2.6 | 1.3 | NA | NA | YES | YES | YES |
| | CL7(187) | 5 | 7 | 71% | 0.9 | 3.1 | 1.8 | 3.3 | 0.7 | NA | + NA | YES | YES | YES |
| | CL8(195) | 0 | 7 | 0% | | | | | 0.5 | NA | NA | YES | NO | NO |
| | CL9(206) | 0 | 7 | 0% | | | | | 0.7 | NA | NA | YES | NO | NO |
| | PCB Sum of Congeners x 2 | 7 | 7 | 100% | 8.0 | 48.0 | 26.0 | 48.3 | 23.0 | NA | + NA | YES | YES | YES |

Notes
[1]Concentration units: Metals (MET) - ug/g; PAHs, PCBs - ng/g.
[a]The range of concentrations reported for site data excludes non-detected values.
[b]1/2 Sample Quantitation Limits substituted for non-detects when calculating mean of site and reference station data.
[c]Minimum benchmark = NOAA ER-L (Long et. al., 1995)
[d]If 95% UCL is greater than the Maximum Concentration, as indicated with a "+", then Maximum Concentration is used to screen against benchmark or background.
[e]Sum of PAH analytes; including biphenyl, but excluding dibenzofuran
NA = Benchmark Not Available
*SVOC

Table C2-3. Target ecological systems/species/receptors of concern for Old Fire Fighting Training Area.

| Habitat | Ecological System/Species/Receptor of Concern |
|---|---|
| Pelagic | blue mussel (*Mytilus edulis*)[1]<br>mummichog (*Fundulus* spp.)<br>cunner (*Tautogolabrus adspersus*)<br>winter flounder (*Pseudopleuronectes americanus*)[3] |
| Epibenthic | blue mussel[2]<br>lobster (*Homarus americanus*)<br>winter flounder (*Pseudopleuronectes americanus*)[3] |
| Benthic | hard clam (*Mercenaria mercenaria, Pitar morrhauna)*<br>soft shell clam (*Mya arenaria*)<br>benthic community |
| Avian Aquatic | great blue heron (*Ardea herodias*)<br>herring gull (*Larus argentatus*) |

[1]surrogate for pelagic species when collected from mid-upper water column (e.g. mooring floats)
[2]representative of epibenthic species when collected from bottom substrate.
[3]present abundances do not permit collection.

Table C2-4. Assessment and measurement endpoints for the Old Fire Fighting Training Area ERA.

| Assessment Endpoint | Receptor of Concern | Measurement Endpoint |
|---|---|---|
| Habitat Quality | Critical habitats | Spatial distribution and extent of habitats. |
| Sediment Quality | Infaunal receptors<br>Epifaunal receptors | Bulk sediment toxicity to amphipods (10-day mortality)<br>Elutriate toxicity to sea urchin gametes (development test)<br>Benthic community structure (diversity, numbers)<br>Abundance and condition of target receptor species |
| Water Quality | Pelagic receptors<br>Epifaunal receptors | Abundance and condition of deployed and indigenous mussels<br>Elutriate toxicity to sea urchin gametes (development test)<br>Abundance and condition of target receptor species |
| Status of Natural Resources | Resource species | Abundance and condition of target receptor species<br>Abundance and condition of potential prey species<br>Bioaccumulation and trophic transfer |

Table C2-5. Exposure point measurements for Old Fire Fighting Training Area ERA.

| Exposure Medium/ Receptor | Exposure Point Measurement |
|---|---|
| Sediment | Bulk sediment and elutriate chemistry<br>Redox potential discontinuity<br>Geotechnical characteristics (*e.g.*, grain size, water content)<br>Ammonia<br>Organic carbon<br>SEM/AVS |
| Water | Water column chemistry (deployed mussel tissue residues)<br>Dissolved oxygen<br>Hydrographic parameters (temperature, salinity)<br>Fecal pollution indicator abundance (deployed mussel tissue residues) |
| Biota | Tissue chemistry<br>Fecal pollution indicators |

# TABLE C4-1. NETC Old Fire Fighting Training Area sample collection and analysis summary

| STA | Sediment Chemistry | | | TISSUE CHEMISTRY | | | | | | Geotechnical | | Water | | | Bioassay | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Bulk Sediment | | Elutriate | Bivalves | | | | | FISH | | | BOD/SOD | DO/NH4 | CTD | | | | | | DBM CI | | |
| NUM | SUR | BOT | SUR | ~~DEP~~ DBM | IBM | Hard Clam | MYA | Lobster | CN/MF | GS | TOC | | TSS/CHL | | HN | DIV | P450 | MICRO | AMP | ~~BM~~ | IBM | Elutriate |
| OFF-1 | 1 | | 1 | DBM | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-2 | 1 | | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-3 | 1 | | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-4 | 1 | 2 | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-5 | 1 | 2 | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-6 | 1 | 2 | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-7 | 1 | | 1 | | 1 | | 1 | | 1 | 1 | 1 | | | | 1 | 1 | 1 | | 1 | | 1 | 1 |
| OFF-8 | 1 | | 1 | | | 1 | | | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-9 | 1 | | 1 | | | 1 | | | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-10 | 1 | 2 | 1 | | | 1 | | | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-11 | 1 | 2 | 1 | | | 1 | | | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-12 | 1 | | 1 | | | 1 | | | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-13 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-14 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-15 | 1 | | 1 | | | 1 | | 2 | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-16 | 1 | | 1 | | | 1 | | 2 | | 1 | 1 | | | | | 1 | | | 1 | | | 1 |
| OFF-17 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-18 | 1 | 2 | 1 | 1 | | 1 | | 2 | | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-19 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-20 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| OFF-21 | 1 | | 1 | 1 | | 1 | | 2 | | 1 | 1 | 1 | 1 | 1 | | 1 | | 1 | 1 | 1 | | 1 |
| REF-IT-22 | 1 | | 1 | | 1 | | 1 | | 1 | 1 | 1 | 1 | | | 1 | 1 | 1 | | | | 1 | 1 |
| REF-ST 23 | 1 | | 1 | 1 | | 1 | | 2 | 1 | 1 | 1 | 1 | 1 | 1 | | 1 | 1 | 1 | 1 | 1 | | 1 |
| T-O | | | | 1 | | | | | | | | | 1 | 1 | | | | 1 | 1 | 1 | | |
| | | | | | | | | | | | | | | | | | | | | | | |
| TOTAL | 23 | 12 | 23 | 9 | 8 | 15 | 8 | 20 | 9 | 23 | 23 | 7 | 9 | 9 | 8 | 23 | 9 | 9 | 23 | 9 | 8 | 23 |

OFF = Old Fire Fighting Training Area
REF-IT = Intertidal Reference Station
REF-ST = Subtidal Reference Station
T-O = Time Zero
SUR = Surface
BOT = Bottom

DEP = Deployed Blue Mussel *Mytilus edulis*
IBM = Indigenous Blue Mussel = *Mytilus edulis*
HARD CLAM = *Mercenaria mercanaria* and *Pitar morrhuana*
LOBSTER = *Homarus americanus*
CN = Cunner (*Tautogolabrus adspersus*)
MF = Mummichog Fish (*Fundulus heteroclitus*)

Discussed Hepatopancreas and Muscle Tissue Agreed. 20, are sample ea.

BOD/SOD = Water Column Biological/ Sediment Oxygen Demand
DO/NH4 = Dissolved Oxygen/ Ammonia
TSS/CHL = Total Suspended Solids/Chlorophyll a
GS = Grain Size Analysis
TOC = Total Organic Carbon

HN = Hematopoietic Neoplasia
Micro = Fecal Pollution Indicators in Mussel Tissue
DIV = Community Structure Analysis
P450 = Cytochrome P450 Assay
AMP = Amphipod Survival Test ← Bulk Sed
CI = Bivalve Condition Index
ELUTRIATE = Elutriate Test With *Arbacia*

larval development only
no fertilization tests - cloudyness algae interferes.